THE AMERICAN

JOURNAL OF PSYCHOLOGY

Founded by G. STANLEY HALL in 1887

VOL. XIX APRIL, 1908 No. 2

A GLANCE AT THE PHYLETIC BACKGROUND OF GENETIC PSYCHOLOGY.

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The background of the genetic aspect of everything is time, which is as indefinable and as primordial as its counterpart, space. There is nothing really actual or conceivably possible that is either spaceless or timeless, and to try to think anything so is stultification. Force, atoms, electrons, souls, thoughts, feelings, and all other activities have position, extent and duration, though we may not be able to measure them. Nothing can be outside of, before, after or independent of either time or space. If the universe were resolved into ether or nothingness, or to die Clausius's heat-death, or to vanish by the slow evaporation of all its solid matters, these would remain unaffected, for they are independent of their content as they are of knowledge. Both are continuous and unbroken, vaster than any imaginable bounds, yet indefinitely divisible. Or if infinity mean only that process is endless, there is nothing transfinitive in the sense of the older theories. They have been thought to be empirical and *a priori*, objective and subjective, have been ascribed to sense, reason, memory, will and special and general feelings, and faculties have been invented as their organs,[1] they are, in fact, more or less involved in every psychic activity, animal or human, concrete or abstract, but their a priority is not logical but genetic, for they are the

[1] For general history of views upon the subject, see Joh. Jul. Baumann Die Lehren von Raum, Zeit. u. Mathematik in der neueren Philosophie, 2 Bde., G. Reimer, Berlin, 1868; also H. Nichols: The Psychology of Time. Clark Univ. Thesis. Henry Holt & Co., New York, 1891.

only truly metaphysical objects. Their universality is not because they are ineluctable factors of thought, but conversely they are the latter because they are the former. Both have their poetry, their religion, also their illusions, phobias and panics. Instead of being the complex mysteries which epistemology and even the usually clear headed Wundt [1] makes them, nothing else is so simple or homogeneous. It is for this reason that knowledge becomes scientific just in proportion as it is exactly defined in their terms, because they are the best known of all things.

To teach them to be mere subjective forms, existent only for us in the sense of Kant,[2] which is oriental in spirit and scholastic in method, is, at the same time, the acme of man's anthropomorphism and conceit of his place in the universe, which in ancient Greece would invite the nemesis of the gods, and is today a crime without a name against the soul of youth just at the time when the passion for certain and objective reality is strongest and when vulnerability to such sophistication is greatest. The objectivity of time and space begins in the very ectoderm from which the nervous system is an infoldment, and to make even the present, which seems the most real part of both, merely specious, despite the fact that to focus everything remote into the magic here and now, is the best definition we have of genius and sanity, is to belie the whole phyletic experience of the soul which acquired through innumerable generations all that is innate in the individual and betrays a subtle mark of incipient mental decay. With the growth of mathematics and a dozen other sciences, our conceptions of time and space, both small and great, have in late years been extended by leaps and bounds, so that the old philosophical ideas of them are far transcended, while psychology has developed rich, fruitful and complex special fields for each. They remain indefinable because by them and by mass all things else are explained.[3]

Time is, at bottom, duration and motion is its measure. Though we can conceive no beginning or end, it is not, therefore, necessarily infinite or eternal, and to ask whether every flitting instant which takes from the future and adds to the past makes the one shorter and the other longer is a vain query. Time contains every causal series that exists at once and

[1] W. Wundt: Die Unendlichkeit der Welt. Essays, 2 te Aufl., Engelmann 1906, pp. 136-184.

[2] Henerle (Die Theorie der Materie) sees in matter only a necessary hypothesis and in the new theories of it only what might have been deduced from the old atomism.

[3] See general conception of space. Adolescence, Vol. 2, pp. 159 and 540. D. Appleton & Co., New York, 1904.

might contain innumerable others. Every effect follows its cause in time, short though the interval be. All histories are forms of construing it. It is irreversible and would go on in the same direction if at the end of some great Platonic era the horology of the temporal order and sequence of all things were inverted and the old grew young and evolution became involution. It would have no gap if all thought and all change stopped for a time and then went on again. It is neither a construction nor an entity. It is not all form or content, concrete or abstract. We cannot affirm that it is finite or infinite, but it defies and transcends all these distinctions as it baffles every definition, but just is, a sun-clear fact, the *primum movens* of all genetic psychology. A recent subtle philosopher[1] makes it a chronic disturber of speculative systems, ever creeping in and making all unstable, and defines time as a negation, as "abstract or dynamic non-being," and the latter as "the genus within which time is the species." If we understand this weird conclusion it is the most flagrant metaphysical perversion of the plain truth about time in a long sad history of them. We must, on the contrary, regard the highest and most complete knowledge or science of anything as the full and accurate description and explanation of all its developmental stages in their temporal sequence. When we can answer the question what occurs at each step, and why, there is no more left to know. Evolution thus, gives a new ideal to, and a higher standard of, noetic values which transcend many lower types, such as definition by genus and difference, classification, deduction from categories, analysis that is introspective, but without perspective. The subordination of these older static methods is in the interests of positive and progressive truth.

Our life is brief and so absorbed with what is near that we are mentally myopic for time. This almost constitutes a new fallacy or idol which impels us to explain all things by their nearest cause, partial though it be, as if this were a law of logical parsimony instead of mere sluggish inertia. Just as it was easier to say that fossil shells on the Alps were dropped there by Crusaders, who we know did carry some as charms, than it was to develop the science of palæontology, so it is simpler to say that the morbid fears of children are due to early frights, and their anger, pity, water, tree and sky-psychoses to their own infant experience, to the exclusion of palæo-atavistic influences. Some regard time as if it were a limited bank deposit so that our economy must be severe and we must admit only grudgingly every new demand lest our account be overdrawn.

[1] J. E. Boodin: Time and Reality. Monograph Supplement of the Psychological Review, October, 1904. Vol. VI, No. 3, 119 p.

Difficulties in the expansion of our ideas of space, though somewhat analogous, were earlier and far more easily overcome. The provincial mind is too prone to regard product rather than process, and finds it hard to realize that everything is hoary with age, that all things we know are in flux, are terminals of a vast past and germinals of a vast future, and that the highest science is the law of change. It is an inveterate habit of thought inherited from ages of superstition that makes us prone, when confronted by seeming breaks or chasms in nature, to fly to some hypothesis of supernal intervention or creationism. The catastrophism psychosis, chronically to prefer unproven revolution to yet unverified evolution, is only a moderate improvement upon miracles. Some appear to feel that they hold a brief either for religion or pedagogy to minimize time, and so urge with almost partisan zeal that the period of authentic history and culture was brief, that man was not tertiary or life pre-Huronian, that the world is really new, etc., as if chronological concepts were in danger of hypertrophy, the sea room of thought restricted, or as if, like valley dwellers, they craved a limited horizon. The opposite tendency is now more scientific, truer, psychologically and pedagogically better, so that if in doubt, and assumption is needful, we should choose the longer and not the shorter time, not merely to indulge the momentum of evolutionary thought, but as an aid to clearer insight and to larger views of the universe.

If all the bodies of our solar system were resolved into nebulæ and uniformly diffused through the sphere of which Neptune's orbit would be a circumference, or if all the matter of the 1000 million suns and yet more dark bodies in our sky were thus diffused, they would hardly dim the passage of the light of a faint star, so infinitesimal is matter compared to the space through which it is distributed. And yet some geologists are now inferring from the structure of the earth, and some astronomers from the composition of meteorites and other heavenly bodies, that, slowly as systems were evolved and rare as collisions are, all celestial bodies have grown up and been resolved back to all stages of chaos by collisions of every kind, degree and angle, perhaps many times, and that the most constant orbits are products of selection of safest paths, so that the entire history of our earth from cosmic gas serves only as unity in computing that of the universe. In the solar system we hear of an ancestral sun that preceded ours, and thus meteors, hundreds of which strike our earth daily, though in one billion years they would add but one inch to its surface they have, nevertheless, in one form of the planetesimal theory, built it up. Indeed, the structure of some of these wandering bodies suggests a destructive and reconstructive history as indubitable as

that of metamorphic rocks. On this view the present visible universe is only one of the countless forms which its substance and energy have taken on, and the oldest objects in any corner of it are novelties to a mind vast and ancient enough to grasp the larger history of its eternal flux. Still more perhaps in the abyss of time, all possible combinations of the innumerable elements of the cosmos may have occurred. Of course all this is utterly unproven, but if we need time beyond the power of the higher arithmetic to compute, we may take it freely.

Hutton[1] thought that terrestrial history showed no trace of a beginning and no prospect of an end, and Lyell[2] despised cosmogony and would have geology accept nothing from astronomy or physics. Only with the rise of evolutionary thought did the problem of the age of the world acquire vital interest.

Suess[3] says that while we can use interstellar distances as unities to aid us in conceiving astronomic spaces, we have no apparatus for geologic time. The age that separates us from common fossils, or perhaps two of them from each other, is, like those celestial bodies, without parallax, which inform us of their physical constitution by their spectrum, but furnish no clue of their distance.

George Howard Darwin[4] holds that the moon broke away from the earth at least 56,000,000 years ago, and, perhaps, much earlier, and that when it did so, charged with steam and gas, pressure diminished as it receded and it fairly boiled with explosions and volcanoes. This, of course, constituted one great epoch in the history of our globe. A second "consistentior status" was when the earth grew solid at a surface temperature of 1200 C°, which Lord Kelvin[5] placed between 20 and 40,000,000 years ago. The next critical period was when the temperature fell to 370 C° and steam became water, a stage which Joly[6] puts between 80 and 90,000,000 years ago. Geikie[7] would be contented with the 100,000,000 years for the whole process. Although the interior of the earth was well on to

[1] James Hutton: The Theory of the Earth. Trans. of the Royal Soc. of Edinburgh. Edinburgh, 1785.

[2] Sir Chas. Lyell: Geological Evidence of the Antiquity of Man. J. Murray, London, 1873.

[3] Edward Suess: The Face of the Earth, tr. by Hertha B. C. Sollas. Clarendon Press, Oxford, 1904-1906. Vol. II, pp. 5, 56.

[4] The Evolution of Satellites. Smithsonian Inst. An. Rep., 1897. Govt. Printing Office, Washington, 1898.

[5] William Thomson Kelvin: The Age of the Earth as an Abode fitted for Life. Smithsonian Inst. Ann. Rep., 1897, pp. 337-357. Washington, 1898.

[6] John Joly: An Estimate of the Geological Age of the Earth. Smithsonian Inst. Ann. Rep., 1899, pp. 247-288. Washington, 1901.

[7] Sir Archibald Geikie: Geological Change and Time. Smithsonian Ann. Rep., 1892, pp. 111-131. Washington, 1893.

solidification, it slowly yielded to great pressure like Barus's diabase, so that as the water sought and found the lowest level the ocean base sank still more and the land parts of the surface were proportionately raised. If with Sollas we assume the total maximums sedimentary deposits to be 50 miles thick, man now lives at the top of 34 miles of vertebrate fossils. Sollas[1] seeks from very many different data on which estimation can be calculated to assign the term of years to each geological age, assuming all the strata together to have a total thickness of 265,000 feet, and the rate of accumulation to be a foot per century, his total time is 26,500,000 years.

To come down to recent ages, estimates of time since life first appeared on earth have been often made by astronomers, physicists, geologists and palæontologists. The bases for induction in these fields differ and hence the results are very divergent, ranging from a few score thousand to hundreds of millions of years. Very different and quite as difficult and conjectural are the attempts often made by geologists to assign absolute or even relative duration to the different geological ages. H. Schmidt and Haeckel present the relation which they think occupied by each of the five geologic evolutionary periods by taking one hundred million years as the age of life and reducing it to one creation day of twenty-four hours. In this case the archæozoic period, occupying 52 million years, would be represented by 12 h. 30 m.; the palæozoic period, to which a duration of 34 million years is assigned, would be 8 h. 7 m.; the mesozoic age (11 million years) would equal 2 h. 38 m.; the cenozoic (3 million years) equal 43 m.; the anthropozoic period (140 thousand years) would equal 2 m.; the historic period (6 thousand years) 5 s.; the Christian era (2 thousand years) between 2 and 3 s.[2] Our individual life is so short that several generations of men would have to summate their exact determinations to prove that the minute hand of a clock, measuring thus the cosmic day, moved at all. The conclusion that it was not stationary would seem dangerous and fantastic to ephemera whose lives endured only a second, however intelligent they might be.

A pupil of Haeckel[3] on a somewhat different basis has actually ventured to estimate the number of generations since vertebrate life began. He begins by assuming that 250 generations at 20 years each would carry us back to 3000 B. C. The *pithecanthropus* is thought by some to have lived near the

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[1] William J. Sollas: The Age of the Earth and other geographical studies. T. F. Unwin, London, 1905.

[2] See Ernst Haeckel's Last Words on Evolution. 2nd ed. A. and C. Black, London, 1899. Tr. from the 2nd ed. by Joseph McCabe.

[3] Ernst Haeckel: The Last Link. Appendix by Hans Gadow. A. Owen & Co., London, 1906. p. 120.

beginning of our last glacial epoch. If we place this 270,000 years ago and assume that this forbear of man attained puberty at 16 or 20, then some 17,000 generations would lie between him and the lowest human tribes. According to Croll[1] and Wallace, 850,000 years take us into the Miocene, with the *pliopithecus* and the *dryopithecus*. If they lived, then, 600,000 years before the *pithecanthropus* and were pubescent at ten, we cannot get less than 60,000 generations. From the apes to the lowest lemurs in the lower Eocene, assuming five years for puberty, we need 420,000 generations. If we go back to the *prototheria*, the earliest known mammals in the Triassic, we must add the whole of the Jural and Cretaceous stage, or in all 5,500,000 years, and assuming three years per generation we get 1,800,000 of these. The whole stretch from the lowest fish to man would be thus resolved into more than five million generations. each of which would mean only a small step. If we admit 17,000 generations between the man of to-day and the *pithecanthropus*, the change in each generation would be too slight to perceive or conceive. So in the change from the fish to the amphibian, if there are one million stages, the marvel rather is that so many generations should be needed to bring about the result. The stretch of time from the lowest fish to the beginning of life is probably vastly greater and the generations certainly succeeded each other far more rapidly.

Taking all the strata where they are thickest, we have a total vertical depth of perhaps twelve to fifteen miles above the simplest Silurian vertebrates, and below this stretch two Palæozoic and five Proterozoic ages and the Archæan complex, together probably quite as thick. Chamberlain and Salisbury[2] think that on the new accretion hypothesis "the real beginning of life on the earth greatly antedated even the oldest accessible formations, so that fossil evidence will never solve the problem of the origin of life." Still these authors prefer the term "archeozoic" to "archean," not because they believe in any form of the Eozoon hypothesis of traces of life in the Laurentian, which in the years 1863-94 was so hotly debated,[3] but because convinced that although metamorphism and other changes have obliterated every trace of it, life originated during this age. Of the geological record as a whole, Darwin said, "I look at the geological record as a history of the world im-

[1] James Croll: Stellar Evolution and its Relations to Time. D. Appleton & Co., New York, 1889.

[2] See T. C. Chamberlain and R. D. Salisbury: Geology. H. Holt & Co., New York, 1906. Vol. 2, pp. 160 and 276.

[3] See G. P. Merrill: Contributions to the History of American Geology. U. S. National Museum Rep., 1904, Part II, Chap. IX, p. 635. Washington, 1906.

perfectly kept and written in a changing dialect. Of this history we possess the last volume alone, relating to only two or three countries. Of this volume only here and there a short chapter has been preserved, and of each page only here and there a few lines. Each word of the slowly changing language, more or less different in successive chapters, may represent the forms of life which are entombed in our consecutive formations and which falsely appear to us to have been abruptly introduced. On this view the difficulties above discussed are greatly diminished or even disappear."[1] This opinion and Darwin's avowed agnosticism concerning the origin of life seem to Haeckel faint-hearted, and in view of the new light which phylogeny and ontogeny now shed upon each other, Darwin would perhaps have modified both views to-day.

The simplest and most generalized types of life doubtless came first, but we can only conjecture its forms before the hard parts, preserved in fossils, arose. Even the trilobites, which abounded in the Cambrian, show marked developmental stages which must have recapitulated a long phyletic evolution of the species. From the very oldest and simplest petrified forms of life to uni-cellular organisms, is a long and intricate way, but now richly set in scene by both classification and embryology. Modern biologists are so infatuated with the marvels of the cell and its parts that they have neglected the stages by which the simplest bit of structureless chromacea or moneron-like bit of protoplasm evolved into the cell. The origin of the former, which is true archigony, is still another problem occupying a vast period of which we know still less.

When we launch out from the farthest shore of microscopic visibility the vast uncharted ocean of the infinitely little stretches before us. The strongest microscope can hardly see the 100-thousandth of an inch, yet a molecule of hydrogen, consisting of two atoms, has a diameter of about one 250,000-millionth of an inch. About one thousand atoms is now the estimate in a highly organized vital molecule, yet we know very definitely that it takes about a thousand electrons to compose a single atom of hydrogen. The green glow inside an airless Crookes's tube, which is due to incandescence set up by a stream of electrons which may be deflected by a magnet as if it were a piece of iron, is caused by corpuscles which can be counted and their charge measured. The rate of leakage of charged bodies surrounded by gases which varies with their pressure, temperature, with light and moisture, have given phenomena which have led within the last few years to epoch-making results con-

[1] Charles Darwin: Origin of Species. 6th edition, D. Appleton & Co., New York, 1904. Vol. 2, p. 88.

cerning the ultimate constitution of matter.[1] The corpuscle and the charge it carries are each known only through the other. The electron is in some sense a mental image, and while it may be a strain or a whirl in the ether, the conservative view is that the corpuscular theory is favored and that Ostwald's energetics, the way to which was paved by Willard Gibbs's[2] views of energy and entropy, are very extreme. The recent studies of radium mark perhaps, the climax of human ingenuity in research. Like every other, the radium atom consists of a whirling mass of particles, some charged with positive and others with negative electricity. From this, probably on account of centrifugal force, some of these charged particles fly off with intense velocity. In passing through a gas they dash to pieces such of its component molecules as lie in their line of flight. So great is the atomic weight and the initial energy of each projectile that it can destroy some hundred thousand molecules before its velocity is reduced 40 per cent. Thereafter its power to break up or ionize the gas molecules declines rapidly. At least seven transformations of the original atom have been traced from radium A to F, and the close relations of these forms of radium to uranium, thorium and perhaps to lead, suggest the transmutation of matter. The loss of each particle causes a change in the properties of what is left behind, which differ greatly as do the different rays, the velocities of which are very distinct, though nearly constant for the same set. When they cause phosphorescence, they seem to do so only by re-enforcing the pre-existing molecular activity of the elements in the substance itself. Aggregates or clusters of these electrified corpuscles, absolutely identical in themselves, probably built up the more than fourscore chemical elements by variations in their number and arrangement—that is, they are *materia prima*. Thus light, heat, electricity, perhaps gravity and chemical affinity are forms of radio-activity, and volcanic force and even life itself are thought by some to be due to it. In the beginning was radium.

It is little wonder that so much energy with so little matter should give an impulse to dynamism, but the saner thought is that these units are more than centres of force and that, small as they are, they have a sub-stratum or core of solid matter. At least they act very like tangible bodies, moving in straight lines, if not deflected, and if they are so, the radii of their curves

[1] See J. J. Thompson: Conduction of Electricity through Gases. Cambridge University Press, 1903. A. Righi: The Modern Theory of Physical Phenomena, Macmillan, 1905. E. Rutherford: Radio-Activity. Cambridge University Press, 2nd ed., 1905.

[2] J. Willard Gibbs: Thermodynamische Studien aus dem Englisch übers von W. Ostwald. Engelmann, Leipzig, 1892.

can be calculated by the same formulæ as apply to the movements of the heavenly bodies. When they are arrested their energy is transformed into heat exactly as when a hammer strikes an anvil, and if they penetrate an atom they lose energy at a rate proportional to the square root of the atom's weight. Still these epoch-making discoveries do make us feel that the world is intensely alive or that its inorganic basis is no less but perhaps more vividly active than life itself, so that if now the soul were thought material it would seem less degraded by its origin, and its resolution into such a sub-stratum would be less repugnant. Even therapeutics has realized new relations between these forms of physical energy and life, and theories of energetics do not oppose but favor the psychic interpretation of the world. All these processes preceded and will outlast life. They are valid in every part of the universe so that their beginning is inscrutable.

Among the chemical elements, carbon, which predominates in nearly every part of plant and animal life, is marked by the number and variety of its compounds. Of these sixty thousand have already been isolated and studied, and yet, although Shenstone[1] estimates that it makes up about half of modern chemistry, the science of this element is still in its infancy. Its fecundity is seen by the fact that it has been estimated that no less than 802 tridecanes may perhaps exist, each of which would have distinct properties and yet could not be distinguished by chemical analysis the one from the other, since each has the same proportions of carbon and hydrogen and the same chemical formula. When it is added that but very few of these 802 substances are found among the sixty thousand compounds known, even the "marvels of radium pale before the possibilities that lie hidden in a handful of soot or charcoal," and we can, perhaps, understand the inspiration of the hundreds of men who for the last fourscore years have devoted their lives to the study of this element alone. The clue to this labyrinth was furnished by isomerism, which designates those cases where several distinct compounds arise from uniting the same elements in the same proportions so that properties of compounds do not depend on the nature and number of atoms in their molecules alone, but also upon the way in which they are arranged. Now there are hundreds of isomerisms and the existence and the properties of undiscovered compounds can often be predicted with a degree of accuracy hardly inferior to that which enabled Mendeléeff by his periodic law to predict

[1] W. A. Shenstone. New Physics and Chemistry. Smith, London, 1906.

the existence and foretell the properties of gallium and germanium.[1]

Another line of work which has loosened the hard-trod soil about the problems of life and mind consists in the exploration of close analogues of vital phenomena in inanimate things. Poets and philosophers have always thought there was a soul in things. Kepler was an animist and thought that the motive force of the planets was their soul. To him, almost as to the ancient hylozoists, the globe was a great animal, sensitive to astral influences, frightened into hurricanes and earthquakes by the approach of other planets. Leibnitz' continuity theory held that there was no inorganic kingdom and nothing quite dead, but a perfect and unbroken continuity, so that every, even a material, monad had a rudiment of both life and soul. Boscowich[2] did not refuse to his immaterial and infinitely small points a kind of low vitality. The alchemists and Hermetic philosophers went yet further. In point of fact, too, everything in nature works. Some rocks and precious stones are spoken of as more vital than others. A metallic rod stretched shows eventually a weak point where it would break, but if it is given a little time to rally, this threatened point is hardened, and when stretching is resumed another weak point is developed. Metallic alloys have a mobile structure. Hammering and torsion have a consecutive effect, almost like after-images. Mercury sweats through iron. Copper is welded to tin by pressure. Glass slowly accommodates to torsion.[3] Wax so hard as to be scarcely indented by the thumb nail, placed in a hole above a cork, with pebbles on it, in a few days shows the cork on the top and the pebbles at the bottom, both having passed through the wax as if it were fluid. If a cylinder of lead be placed on a disk of gold and kept in boiling water, which is far below the melting temperature of both these metals, in six weeks shows the gold diffused on the top of the lead cylinder. When annealing breaks down a crystal form the molecular displacement finds a new equilibrium. Bose[4] found that tin and other metallic wire, after the passage of an electric current, required various periods of recovery, and that there were even analogies to tetanus, both complete and incomplete. Some wires show

[1] D. Mendeléeff: The Principles of Chemistry, translated from the Russian, 6th ed., by George Kamensby. Longmans, Green & Co., London, 1897. pp. 26-90-124.

[2] William Thomson, Lord Kelvin: On Boscowich's Theory. Smithsonian Inst., An. Rep., 1889. Washington, 1890. pp. 435-439.

[3] For a collection of similar instances see Albert Dastre: Life of Matter. An. Report of the Smithsonian Institute, Washington, 1902-1903, p. 393.

[4] Jagadis Chunder Bose: The Response of Inorganic Matter to Stimulus. Royal Institution Lecture. W. Clowes & Sons, London, 1901.

fatigue analogous to that of nerves if acted upon for some days. Some chemical substances stimulate and others depress and poison action in both wires and nerves. Bose even constructed an artificial metallic retina, responding to color and with oscillations after the cessation of light, not unlike those shown in the retina. Many other phenomena raise anew the question where to draw the line between physical and physiological processes, as if life activities were foreshadowed in things without life, and above even this great distinction there were a larger unity in and through all. Not only memory but hysteria have been used to designate the behavior of bodies subjected to magnetic and other forces. Again, the Brownian movements, seen in microscopic dust in a liquid which is suspended in water, never cease, for they are found in quartz crystals which at the moment of their formation enclose a cavity of water containing a bubble of gas. Only in 1894 was it more or less explained by Gouy as an oscillation of independent particles, the larger moving slowly and the smaller most active. They are not vital because seen in boiled liquids, and the movement does not depend upon the nature or form of the particles or of the liquid unless it is viscous. They are independent of the tremors of the earth and seem to be molecular movements that invite us to study the far more subtle ones of the kinetic theory.

Crystallization approaches most nearly to life. Crystals grow from the surface by apposition rather than, like germs, from within. They assimilate by a process that mimics nutrition, and may attain a great size. If the mother lye is removed their development is suspended like a seed kept from soil and moisture. Each tends to carry out its own architectural plan and heal wounds, restoring mutilations more rapidly where they occur than it increases at other points. Ismorphism, or their power to replace each other, is comparable to inbreeding or crossing, which is the touchstone of taxonomic relationship. Crystallization is very closely associated with simpler vital organisms in their hard parts, bone and shell. Something like reproduction occurs and crystals are sown like micro-organisms. Liquids in suffusion are especially favorable media for propagating certain kinds of crystals and contact of such a fluid with any crystal germ by an object not sterilized sets up at once the process of crystalline organization which spreads through the mass. In Ostwald's salol the crystals may measure less than one one-hundredth of a millimeter on each side and in hyposulphate of soda they measure a thousandth of a millimeter. Sometimes they are spontaneous generations where the optimum conditions of a solution occur. Often the latter cannot be reproduced and so crystals can be generated only by

infection or filiation. Perhaps the most striking instance of this is the famous glycerine which crystallized spontaneously in 1867 in a tun sent from Vienna to London in the winter. No one saw these crystallize and the conditions under which they occur were entirely unknown until recent years. They have been also accidentally formed in a French factory, and only, so far as known, in these two cases. They appear just as living forms do in a favorable environment and spread only as the Promethean fire did by direct contagion of flame or coal, or as magnets were made only by contact with other magnets before electro-magnetism. The crystals of 1867 have already a very extensive posterity. One factory produces them on a large scale. As they melt at a temperature of 18° C., a single summer might for a time exterminate the whole species.

Most matter is not amorphous but crystalline, and snowflakes, sand, rocks, minerals and most solids in solution tend to take on forms of marvellous intricacy, beauty and mathematical regularity, which are very diverse and of characteristic structure. This used to be explained as a *nisus formativus* of nature. The analogy between the framework of plants (which inclined Sachs[1] to the view that plant protoplasm is at bottom crystalline), as well as the skeletal forms of many lower animal forms and crystals, is very suggestive and has long been provocative of speculation; and now that crystallography is experimental, this morphologic principle seems increasingly life like. The physicist Lehmann[2] has summed up our knowledge of the structure of doubly refracting colloids, many of which strikingly suggest cells, fibres, and other biological patterns, karyokinetic figures, etc. While admitting that protoplasm has a structure that both expresses and directs molecular force, he discredits all strictly vital functions. Schenck[3] supplemented this work from the standpoint of a physical chemist with quantitative measurements of anisotropic substances. These studies show that besides solid crystals there are manifold others of various degrees of plasticity and fluidity in colloids, the consistency of which resembles the softer and most vital parts of living substance. Von Schrön[4] less temperately concludes, from a study

[1] Julius von Sachs: Vorlesungen uber Pflanzen-physiologie. Engelmann, Leipzig, 1887.

[2] Otto Lehmann: Flüssige Kristalle. (With many photographs on 39 quarto pages.) W. Engelmann, Leipzig, 1904. Also his Theorien des Lebens.

[3] Rudolf Schenck: Kristallinische Flüssigkeiten und flüssige Kristalle. W. Englemann, Leipzig, 1908. 1905.

[4] Biologia Minerale. Lettera del Prof. Otto von Schrön al Prof. G. B. Milesi. Estratto dalla "Rivista di Filosofia e scienze affini" Ottobre, 1901. Anno. III, Vol. V. N. 4. Zamorani e Albertazzi, Bologna,

of what he calls the growth, behavior and generation of crystals, that everything in nature either lives or has lived. All young crystals, but not old and fossilized ones, are alive. His greatly magnified photographs show, he thinks, that "petroblasts" or bioblasts pass through certain stages before they are usually called crystals, which latter term designates a degenerate though perdurable stage. Here, too, probably belong Leduc's[1] so-called artificial cells of potassium, ferrocyanide and gelatine, and also Dubois's vacuolids, or, as he now calls them, eobes, produced by barium and manganese salts in sterilized boullion. Burke's[2] now much debated radiobes, so named to chime with microbes, arise when particles of radium are sprinkled on jelly-like decoctions of nutritive substance rendered antiseptic. These structures seem to develop nuclei, to grow by physical metabolism, bifurcate, adjust inner to outer relations, etc. Though aggregates of crystals, they are not, we are told, exactly crystals nor colloids in disguise, but add to this the most primitive elements of vitality. Although "on the bounds between crystalline and organic bodies, they cannot properly be called living, but correspond to some simpler form of life that existed in a distant age."[3]

Not only crystals, but certain foams, resemble cells or tissues. Quincke[4] found in solutions of silicic acid, glue, etc., after evaporation, fibres, fissures, tubes, bubbles and often vacuoles which are either open or closed, join each other or do not, according to the viscosity of the oily liquid. They seem to grow and shrink by diffusion in water. The inclination of their walls, surface-tension and refraction also change with the concentration of the medium. He thought them cellular, yet

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1901. Also Le due Conferenze dimostrative ed una Comunicazione fatte a Napoli al Congresso contra la Tuberculose nel 1900, dal Prof. Otto von Schrön. Estratto dagli Atti del Congresso. R. Pesole, PiazzaB ellini n. 6, Napoli, and Brevi cenni sulla conferenzo dimostrativa su materia e forza (uno dei capitole della vita dei cristalli). C. Sciarrino, Palermo, 1906.

[1] Stephane Leduc: Cytogenise experimentale. Ajaccio, Paris, 1901.

[2] J. Butler Burke: The Origin of Life; Its Physical Basis and Definition. Chapman and Hall, London, 1906.

[3] These studies should tend to rescue from discredit R. Altmann's attempt (Die Elementarorganismen und ihre Beziehungen zu den Zellen, Veit & Co., 1894), to resolve protoplasm into ultimate granules which he called bioplasts and thought to be ultimate vital units essentially crystalloid in nature. These were within the range of the microscope, regularly disposed in viscous intergranular substance, and, though differing in form, were essentially homogeneous. His mistake was in describing as granules various components of the cell known to be both different and secondary.

[4] G. Quincke: Ueber periodische Ausbreitungen Flüssigkeitsoberflächen und dadurch hervorgerufene Bewegungserscheinungen. Annal. der Physik u. Chem., Neue Folge, Bd. 35, No. 12, 1888. p. 580-642.

soluble. Bütschli [1] studied for years emulsions of soluble salts and thinks the structure of photoplasm is like fine soapsuds or beer, crowded and flattened like the bottom of honeycomb cells. Under the microscope these structures show spontaneous flowing movements, explicable by physical principles. Foams have since been much studied as a new avenue of approaching the mysteries of life. By others, such alveolar structures are interpreted not as globules, but as fibrillar, like the threads constituting a sponge. Flemming, especially, thought primitive plasm to be filar and showed that such network structure, the fine threads of which are sometimes isolated and sometimes bundled together, which play an important rôle in cell division and are prominent in large ganglionic cells, is common in cells and can be more or less imitated by coagulations. They are, however, probably a secondary phyletic product. Enzymes and catalysors which set up processes in substances, themselves remaining unchanged, although they shed valuable light upon vital processes, cannot explain the origin of life.

Yet more valuable and stimulating is the recent effort to explain the elementary phenomena of life and its developmental processes by the general principles of physics and chemistry.[2] Capillarity accounts for the sphericity of cells as of dewdrops from diffusion over surfaces. Contact, adhesion, solubility and positive chemotropism are the key to primitive food-taking as absorption is of rudimentary digestion, and excretion of chemical repulsion. The appearance and disappearance of vacuoles are osmoses. The marvellous radilarian framework is due to the mechanism of fluid crystals. Artificial substances perform some, if not most, of the characteristic amœboid movements which are always toward points of least and from those of greatest surface tension which is ever changing under the influence of temperature and many inner and outer influences. Ciliary motion is reduced to metabolic disturbances of myeline threads. Roux's [3] reduction of bifurcation to positive and negative cytotropism, the mechanical imitation of spindles,

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[1] J. A. O. Butschli: Untersuchungen über mikroscop. Schäume u. das Protoplasma. W. Engelmann, Leipzig, 1892.

[2] Represented in the Arch. f. Entwickelungs-Mechanik der Organismen, founded in 1889. See in this Archiv. Ludwig Rhumbler: Physikal. Analyse in der Lebens erscheingungen in der Zelle. Oct., 1898, Bd. 7, pp. 103-350, 100 figures. See, too, his Zellen-Mechanik im Zellenleben. J. A. Barth, Leipzig, 1904. Various articles in Ergebnisse der Anatomie und Entwickelungsgeschichte during the last 10 years. Also Dr. Paul Jensen, Untersuchungen über Protoplasmamechanik. Pflüger's Archiv. Nov., 1901, Bd. 87, s. 361-417.

[3] Wilhelm Roux: Der Kampf der Theile im Organismus. W. Englemann, Leipzig, 1881. Ueber die Bedeutung der Kerntheilungsfiguren. W. Engelman, Leipzig, 1883.

rays, cell division, gastrulation and other cytokinetic or embryological processes, Boveri's[1] interpretation of the nucleus as a storehouse of energy and matter, the most-of-all-discussed karyokinetic figures partly reproduced artificially by Bütschli, illustrate this field. The best of this vigorous group of investigators by no means attempt an ultimate explanation of the nature and origins of life, although very outspoken against the neo-vitalists, but they do show that many of its first and simplest manifestations are physical and chemical processes and are best described in the terms of these sciences. Certainly points, currents, gravity, light, heat and all the great cosmic forces to which living forms respond by the many tropisms, tonuses, taxies, kineses, etc., suggest that the rapport between life and its environment, although at first closer than now, is still very intimate.

The above attempts to derive life do not altogether explain the reverse of the universal process of death even in the simplest organisms. Were this done, the origin of life would be resolved into that of matter itself, and the curious question suggested by Roux would arise—into what species, plasm made in the laboratory and without heredity, would evolve, and, we may add, what kind of soul stuff these *eobionta* would have. Celluloid crystals, foams, surface tensions, etc., do suggest that nature may have made countless abortive attempts to produce life, that this was her longest and hardest task, occupying all the vast Archæozoic age, that many methods that we can now partly reproduce were eliminated by selection, and that many more of them culminated in the development of a matrix of physical conditions under which the vital spark was at last struck, and the process of developing plasms may have been going on from the first. Very likely the chasm between all these artifacts and life is so great that all the first and longest geologic age was necessary to bridge it. It is not impossible that at its advent life, instead of being akin to the lowest forms now known, was very different and is now a missing link.

Three other notable theories of the origin of life are the following: In 1865, following a suggestion of Liebig's, Hermann Eberhard Richter, reviving and definitizing old speculations, proposed the theory that germs of lower organisms, detached from rapidly moving celestial bodies, were floating through space, and that life was inseminated on this earth by them. There was thus an interplanetary exchange of germs, and wherever these found a stage of development with warmth, moisture, etc., favorable to life, they adjusted themselves with

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[1] Theodor Boveri: Ergebnisse über die Constitution der chromatischen Substanz des Zellkerns. G. Fischer, Jena, 1904.

great plasticity to new environments. Assuming that somewhere in the world, planetary bodies had always existed with life upon them, the latter was assumed to be eternal, and the problem was how these cosmozoa were transported from one world to another. Traces of carbon and petroleum-like substances and, indeed, something akin to humus, are often detected on meteorites. These germs, he assumed, might live a long time in great desiccation and without food, like the spores of micro-organisms in a condition of apparent death. Helmholtz[1] and Sir William Thompson[2] have commented not unfavorably upon this possibility. Not only do meteorites have carbon compounds, but the spectrum of the light emitted from the heads of comets suggests gases containing carbo-hydrates. In passing so rapidly through our atmosphere only the surface of large meteorites is heated. In view of all the failures to demonstrate abiogenesis, Helmholtz thought it a fully justified scientific process to inquire whether life be not thus as old as matter.

Perhaps the boldest theory is that of Preyer[3] (1880) that living substances are primary, and lifeless material is a secondary secretion from it. He assumes that we must emancipate ourselves from the arbitrary and factitious idea that life can exist only on a protoplasmic basis. Primevally the whole substance of this earth was a giant organism of fiery fluid or gaseous matter. The entire movements of and within it were its life. As, however, it cooled, substances like the heavy metals solidified or died and step by step ceased to take part in the life of the whole, and the first dead inorganic masses were formed. As cold progressed and the surface of the earth grew rigid or dead, and the chemical elements were differentiated from what remained, combinations resulting in protoplasm became possible.

Pflüger's startling theory[4] now incorporated into the scheme of Haeckel,[5] assuming that plasma is due to the properties of albumen, first points out the marked difference that while living albumen can decompose itself, dead albumen, as, *e. g.*, in the white of an egg, maintains its integrity for some time.

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[1] H. von Helmholtz: Popular Scientific Lectures, trans. by E. Atkinson. Longmans, Green & Co., New York, 1903. p. 196.

[2] Sir W. Thompson:, Report of the British Association for the Advancement of Science, 1871. pp. lxxxv-cv.

[3] W. Preyer: Naturwissenschaftliche Thatsachen und Probleme. Paetel, Berlin, 1880, and Ueber die Erforschung des Lebens, Mauke, Jena, 1873.

[4] E. F. W. Pflüger: Physiologische Verbrennung in Lebendingen Organismen. 1875.

[5] Ernst Haeckel: The Wonders of Life. Harper and Brothers, New York, 1905. p. 345.

This instability of the former is due to the intra-molecular oxygen stored up which dissociates its complex molecules and forms new groups, *e. g.*, water of its hydrogen and carbonic acid of its carbon. In their non-nitrogenous elements the decomposition products of living differ a little from those of dead albumen. But the nitrogenous products of living far exceed and differ radically from those of dead albumen in producing creatin, the nuclein bases, guanine, etc., all of which as a marked characteristic either contain cyanogen (composed of one atom of carbon and one of nitrogen as a radical) or else like uric acid can be made out of its compounds. Hence Pflüger[1] infers that living albumen always contains cyanogen and dead does not. Now living albumen and cyanic acid are both transparent at low temperatures, but set and darken with heat, while with water both break up into water and ammonia and both produce urea, the first organic substance to be artificially composed by Wöhler[2] (1828). Both have great power to incorporate into their molecules other like components and to grow catenally or by chains. Hence Pflüger concludes that cyanogen is a half living molecule and that in it life begins. The first albumen was alive. A constant molecular weight is not necessary for these monstrous molecules, in size like the sun compared to small meteors, and which are incessantly growing and diminishing. Hence the question of the origin of life resolves itself, according to this chemical train of reasoning, into that of the origin of cyanogen. We thus find ourselves confronting the remarkable fact that cyanogen and its compounds can only arise in intense heat, so that they may have originated while the earth was wholly or in part in a fiery condition. Moreover the other essential components of albumen, like the carbo-hydrates and the alcohol radicals, can arise synthetically at high temperatures. Hence life arose from fire, and the long ages during which the earth's surface has been cooling gave plenty of time for the many polymeric formations. The very easy decomposability of compounds into which this root of life enters, and its close relations to carbon compounds were maintained after water arose; and from the chemical relations with its dissolved salts and gases evolved the living albumen, and while they did not produce anything with the morphological value of cells, they enable us to trace the origin of protoplasm. Of course there was a long series of intermediary stages between the most developed Vulcanic pryozoic radical and the simplest living plasm, and Neumeister[3] and

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[1] E. F. W. Pflüger: Archiv. für Physiologie, 1875. Bd. 10, S. 251-367.
[2] F. Wöhler: Annalen der Physik und Chemie, 1829. Bd. 15, S. 525.
[3] R. Neumister: Betrachtungen über das Wesen der Lebenserschein ungen. G. Fischer, Jena, 1903.

other vitalists have urged that this chasm is impassable, although living albumen always does contain cyanide or products of its compounds. To the graver objection that such heat compounds would perish when water appeared, it can only be said that during the immense period yet remaining to be bridged after the closest approximation, both chemical conditions and processes which transcend the limits of even that great science, may have prevailed.

As to the size of the smallest bits of matter to which we can attribute life, several writers have made interesting estimates. Errera[1] estimates the limit of smallness of organism based upon a special study of one Micrococcus of the diameter of 0. 1 μ which, he estimates, contains something like 10,000 molecules of albuminoid substance and 3,000 atoms of sulphur. After making several such estimates he concludes that we may say with a degree of probability, which is of the same order as the probability of the molecular theory of matter, that there can exist no organisms which are to ordinary bacteria as these are to higher organisms. Thus there can be no living creatures hundreds of times smaller than those now known, so that the great spectacle of life unfolds within relatively narrow and well determined limits. McKendrick's[2] estimates are yet more interesting and exact. He thinks the smallest particle that can now be seen under the best microscope is about one 20-thousandth of a millimeter in diameter. That certain bacteria are smaller than this is shown by the fact that after porcelain filters strain out all that can be seen, the filtered liquids infect with certain diseases and kill as quickly and surely as do unfiltered cultures, indicating that it is the microbes themselves and not their toxines that are fatal. Weismann assumes the diameter of a molecule to be one 2-millionth of a millimeter, and that a biophore contains some 1,000 molecules. Its diameter would then be one 200-thousandth of a μ, or ten times too small to be seen. Thus a cube, one side of which was one 1-thousandth of a μ would contain 8 million biophores, and a red blood corpuscle between 3 and 4 thousand million of them. The smallest visible particle may contain 1,250 molecules, for there would be 125 in a biophore. The head of a spermatozooid, of which man produces 340,000 million dnring his sexual life, is estimated to contain 25,000 million, and the fecundated ovum 25,000,000 million organic molecules. Even if each molecule contained 10,000 atoms there would be 1,000 million of them. On this

[1] M. L. Errera: Sur la limite de petitesse des organismes. Rev. Scientifique. Feb. 7, 1903. 4e Sèrie, Tome 19. p. 169-172.

[2] John G. McKendrick: Presidential Address. Report of the British Association for the Advancement of Science. Glasgow, 1901. pp. 808-816.

basis each human spermatozoon would contain 250 billion atoms or 250 billion elecluns. This would be only the contribution of the male to his offspring; the far larger ovum would contribute more. Hence, although there are estimated to be 60 trillion cells in the adult human body, there are enough elements in the germ plasm to account for the heredity of all the qualities which connect us with our forbears for countless generations, and to allow each individual to contribute something to all his posterities without drawing upon ulterior atoms or electrons with which life is probably in some unknown way continuous. While, like most biologists, Weismann, *e. g.*, thinks life demands a definite combination of different kinds of molecules and says, "A single molecule cannot live, can neither assimilate nor grow nor reproduce." Haeckel objects, for the plastidule he assumes is a single plasm molecule to which he ascribes not only these powers but memory in Hering's sense. Verworn's[1] biogens, of which plasm is composed, may also be single molecules which may or may not be homogeneous. The plasmogony they effect is not a mixture as Hertwig opines, nor does symbiosis of independent elements explain the nature of the higher units. They are rather like electrons, postulates for economic thinking, and their reality is closely analogous to that of God, freedom and immortality for Kant's practical reason. Although most of them are metamicroscopic, they are not too small to play the marvellously complex rôles assigned them. The secrets of the origin of soul are now more and more clearly seen to be bound up, if not identical, with those of the origin of life, and the beginnings of both stretch back ever farther in time and down the scale of simplicity, so that their primordial germs must be coeval with the dawn of matter and with time itself. Although, as we know them in their present forms, they seem incommensurably different from the life of the physical universe, they are, in fact, products of an evolution that has proceeded by insensible gradations with no rupture of identity.

We next glance at the most characteristic of the more complex vital units, which in modern biology play a part psychologically very akin to that of categories and innate ideas for the philosophers of some generations ago. Nägeli[2] estimates that there are 100 billion of his micellæ in a single moneron of 0.6 m. in diameter. If one of the former has a diameter of 0.0006 m. it would still have millions of ultimate parts, but a single molecule cannot be said to live. The micellæ are not

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[1] Max Verworn: Die Biogenhypothese. G. Fischer, Jena, 1903.

[2] Karl Wilhelm von Nägeli: Mechan. physical, Theorie der Abstammungslehre. Oldenburg, München, 1884. Sections 1-5.

themselves living but are so composed as to give rise to life. We can never observe their origin, since their development from an inorganic basis is not an empirical datum, but a result of reasoning from the laws of matter and force. This primitive abiogenesis occurred many times in the past and still occurs, and may occur at any time and place, so that life is polygenetic. In general, the most evolved forms have perhaps the oldest pedigree. Simple forms that have remained at the lower stages of evolution may now be many times reproduced. The micellæ strongly tend to combine into chains and ropes in a crystalloid way, and this arrangement conditions all the later developmental differences of species in an almost fatalistic predetermining way not consistent with the plasticity demanded by broad selectionists. Variation is thus definitely directed and to a great extent independently of the conditions of the environment. His evolutionism is so extreme that morphology and taxonomy are called phylogenetic sciences, but all goes on from the momentum of an internal principle which he calls isagitation (from ἰσάζω, to make equal). Inherent in nature is an impulse to perfection, and over all his idioplasm is a kind of *nisus formativus*, which plays upon the rows or threads of micellæ like a pianist on keys. His earliest probionta, plassonella or young monera are not structureless organisms without organs, but are nearer to unicellular algæ, and over against the hereditary matter of idioplasm is the trophoplasm, which is the nutritive part of the cell. He thinks, as does Weismann, that life probably arose in a reticulated superficial layer of fine porous clay or sand, where the molecular forces of solids, fluids and gases could best co-operate. Under their influences these biophoridæ acquired the power of assimilation such as plants have, then of multiplication, and finally were able to cross the threshold of microscopic visibility, although, perhaps, after enormous periods of time, for before any advantages of differentiation could occur, biophores must have made stable associations into colonies. Nägeli finally thinks that if even molecules have anything like sensation it must be agreeable to them to follow and painful to depart from their attractions and repulsions. Hence, he assumes a spiritual or psychic bond throughout all nature, of which the human mind is only the highest development.

Haeckel's[1] plastidules are chemical molecules which can be

[1]Ernst Hackel: Natürliche Schöpfungsgeschichte. 1st ed., G. Reiner, Berlin, 1868. Systematische Phylogenie, G. Reiner, Berlin, 1894-06 3 v. See also The Last Link, tr. by Hans Gadow, 2nd ed., A. and C. Black, London, 1899. The Riddle of the Universe at the Close of the Nineteenth Century: tr. by J. McCabe, Harper and Brothers, 1901. The Wonders of Life: tr. by J. McCabe, Harper and Brothers, New York, 1905.

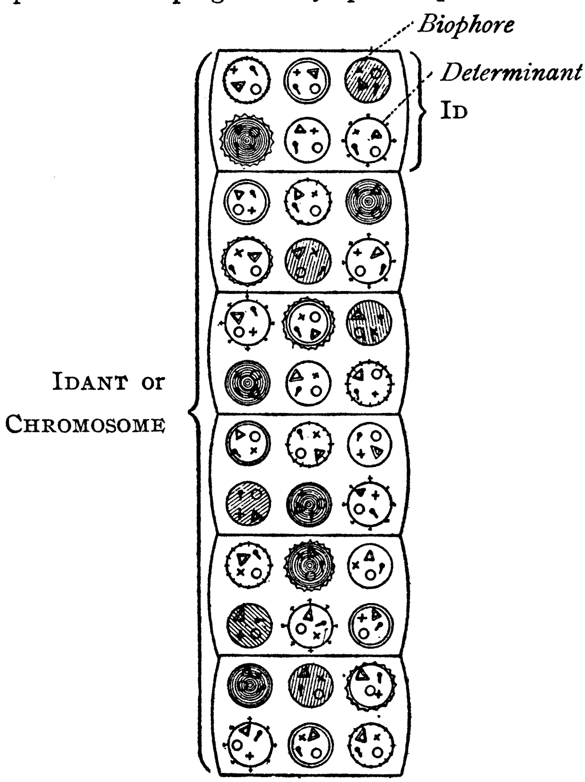
decomposed only into atoms. Hence they cannot divide but they can cause the production of new ones from a nutritive fluid. In a broad sense everything lives, even atoms, for their attractions and repulsions suggest pleasure and pain, but their will and sensations are invariable. In a stricter sense, life is reproduction and that is essentially memory, and this plastidules have, but lifeless things lack. Primordial memory is a mechanical result of the mode of movement of the elements of the blastidules. Their first organisms are monads or now chromacea which grow, as it were, by precipitation of new plastidules and then reproduce by division. At first, they are homogeneous and alike, but the environment adds new inner movements to those pre-existing and these adaptations are transmitted. This differentiation is perigenesis. Each new individual passes rapidly through the stages of its stirp, guided by the unconscious memory of the plastidule, which in higher organisms have both learned and forgotten much, but in lower ones have learned little and forgotten nothing. All the ontogenetic processes of one generation from egg to egg are comparable to a wave with smaller waves representing the successive cell divisions that form and develop the organs during growth, while the history of a species is a larger wave: but since environment changes, the crests and hollows of even these waves are not a straight line, but themselves make a larger wave curve representing the entire history of life. Perigenesis is the efficient cause of this complex and ramified undulatory reproduction of the plastidules. Life has one origin and Haeckel boldly constructs many elaborate genealogical trees for various phyletic groups of animals and plants, Man is given a very elaborate pedigree from the plastidule up. Acquired adaptations are inherited in a Lamarckian sense. He abhors teleology, has been himself a great ferment, stimulated many pupils, and has in recent years popularized his ideas in many papers and several books.

Weismann,[1] who, next to Darwin, is probably the ablest of biological thinkers, has since 1875, wrought out a theory of life that fits and unifies a vast body of facts, and in his last volumes gives a final formulations of most of his views. Life arose by chemical spontaneity long before the first fossils. The primitive *biophoridæ* were produced after countless failures and

[1]August Weismann: Essays upon Heredity and Kindred Biological Problems. Authorized trans. 2nd ed., Clarendon Press, Oxford. 2 v. 1891-92. Studies in the Theory of Descent, translated and edited by Raphael Meldola, S. Low, Marston, Searle and Rivington. 2 v. London, 1882. The Germ-Plasm, tr. by W. Newton Parker and Harriet Rönnfeldt. C. Scribner's Sons, New York, 1893. The Evolution Theory, 2 v., tr. with the author's co-operation by J. A. and M. K. Thomson, E. Arnold, London, 1904.

extinctions, but eventually with a wealth so inexhaustible that vastly more species than ever did evolve might have done so from them. This process, perhaps, occupied more time than all that has since elapsed. These biophores are the smallest units that can assimilate and reproduce, but they are extremely diverse. At first they aggregated, then organized in innumerable ways and relatively few of these products survived and only the fittest of them slowly advanced towards microscopic size. Even if we could compose the conditions for spontaneous generation, we should probably never know that it had occurred, so minute would be its first products. Everything that lives grows and divides so that there was no death at first because there is nothing like a corpse to be sloughed off. Hence, barring accident, the lower forms of life when once started were potentially immortal and from these most ancient beginnings all living forms are developed by a direct continuity of descent. Plasm is like a fluid poured over nature, preserving its every feature, so that their vital structure, large and small, has a definite cause in the environment, to trace which historically for every cell, organ, species and corm is our goal. No one has given such extension to the principle of selection which is germinal, histonal and personal. Each biophore, tissue and individual struggles to survive and in so doing competes for nutriment and space with every other in each individual body. There is ultimately no predetermination and every species is like a traveller and may depart indefiniteiy from its origin and wander about as the environment favors or opposes. When the cell arises the chromosomes contain both cytoplasm, which presides over ontogenic growth and nutrition, and also idioplasm or ancestral plasm, devoted to reproduction. In the former, cell division is differential and produces parts ever less general and more special. Germ plasm, however, divides identically. Instead of disintegrating to form a soma which dies, it is perpetuated indefinitely through successive generations now in the highest as it was originally in the lowest organisms. There may be at a certain critical stage a struggle between the two, and the ancestral elements may overcome and expel the histogenic plasm which makes the body and thus constitute a reproductive instead of a somatic cell. Biophores may be massed into determinants and one, at least, of these presides over every part of the body that can vary independently of other parts. Ids are groups of determinants which comprise all of the ancestral plasm necessary to build up an individual. Very early in the embryo the two kinds of plasm are separated, that for reproduction being set apart as latent for subsequent generations, ready to develop when their time comes. So isolated and protected is it that all the events in the life of the individual

barely affect it and hence acquired qualities are not inherited. To the vindication of this extreme position a wealth of concrete discussion is devoted. Higher yet are the idants which may contain a hundred different ancestral plasms and which is used to explain atavism. Though all these processes cannot be traced in detail, they, in fact, pass over definite tracts and through distinct stages. Even the parts and organs produced by the first divisions in ontogenesis, he seeks to trace as the cells slowly specialize and lose the reproductive power originally inherent in all. In a sense, development into classes, orders, families, genera, species and individuals is thus the disintegration of germ plasm as its progressively specific qualities come



This diagram (for Lotsy's Deszendenztheorien. Fischer, Jena, 1906) illustrates how, although the chromosomes divide equivalently, this does not involve equivalent diversion of the ids. Hence certain groups of determinants may be lacking in some cells, which would therefore have only a part of the hereditary qualities and so could no longer reproduce a new individual.

out. When maturity is attained each single cell has its directing biophore. Each vital element is intrinsically different and is not made so by its position or environment, as Hertwig's epigenesis holds. Germ plasm acquires more and more potentialities up the ascending stages of life, so that although it was at first very simple, it is now for the higher types extremely complex. Plain as this abstract of his theory seems, it becomes indefinitely complicated and requires various ancillary assumptions when he seeks to explain by it, as he does in great detail, the various functions of heredity, variation, regeneration, hybridism, alternation of generations, amphimixis, atavism, parthenogenesis, infection, and most of the other great problems of plant and animal life.[1]

De Vries[2] thinks that variations as now tabulated in curves, showing their range in the same species, are too small to produce the latter by gradual departure from the parent form. He also holds that crossing cannot produce permanent qualities that are also really new, but that, after breeding true for a series of generations, there comes a period of saltatory variation or mutation, and that this is the chief agent in producing new forms. Selection, thus, has a limited range and can only

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[1] Mention should perhaps here be made in passing of what is in some respect the counterpart of Weismanism, recently developed by a few pathologists, Cohnheim, Jensen, and Beard which is rudely as follows. Alternation of generations means that at intervals an individual is produced which does not develop but stops at some lower ancestral stage, the next generation reverting to the full normal of the species. This is usually thought to occur only in very low forms but it is now believed that it holds in a changed way in metazoa and even man, both of which have larval structures which degenerate. The embryo proper develops on the larval bases which do not thus constitute new organisms but are the foundations on which development begins *de novo*. These transitory structures or embryonic residua constitute the trophoblast and at a critical period when the pancreas develops trypsin, they are digested as its alkaloids supplying the formic acid intra cellular digestion. This responsible issue has the same continuity as germ plasm, only it is as the cells, and these aberrant germ cells are found in all parts of the body of the young, arising outside of it and migrating into it. They wander anywhere along different paths, but some never reach their goal in the sex organs, and are misplaced but do not degenerate. The embryo is a product of one of the primary germ cells, while the rest are its twin brothers. Instead of producing trophoblastic tissue they may degenerate and sink to a low plane of rapid multiplication and lose the power of building tissue. Although these perverted germ cells tend to produce new individuals they are able only to produce larval, sexual trophoblastic tissues and these may produce a ferment called malignin which destroys the health cells of their host. This is cancer, which causes about one death out of forty.

[2] Hugo de Vries: Species and Varieties, their Origin by Mutation. The Open Court Pub. Co., Chicago, 1905. Intracellulare Pangenesis. Fischer, Jena, 1889.

explain the survival but not the arrival of the fittest. This view is favored by the gaps in the palæontological record. To the illustration of this thesis and its defense against his many critics, he has massed a vast area of facts from a wide biological field. His pangenes are the smallest chemical substances that can assimilate food, grow and divide, and although vast in numbers they are of limited kinds, so that just as the letters of the alphabet compose all words, they can make all living forms. In the simplest creatures all the pangenes are few and act concurrently, but in the higher forms of life they are more numerous and of more kinds. They may long rest quiescent and then mass themselves and surmate their activities in the molecular plasm. Here they multiply and each nucleus stores up all the pangenes of an individual, becoming thus the organ of heredity. From here they migrate at intervals and form new individuals. At first every cell can reproduce itself from the pangenes resulting from the first divisions which are alike. Soon for some this generative power lapses into that of growth only because the cells that compose the body do not receive a complete set of pangenes, for it would be useless to burden them with those for which they have no use. Before long, however, the somatic development becomes unique and apart. Pangenes are distributed not like Darwin's, by permeating all tissues, but always at the moment of division, so that their movements are always confined within the limits of the cell. They have their phylogeny like species.

J. Reinke[1] represents a totally different point of view. Like Lotze, he lays great stress upon the difference between mechanism and teleology, is a dualist and a theist. After pushing physical and chemical explanations to their uttermost, as he always tried to do, and insisting that every form of life is a chemical factory and pervaded by systems of force from the sun, which all structure is to conduct, he finds reproduction, nutrition and sensation to be inexplicable because they have no analogies in nature. Hence he is led to postulate teleological forces not unlike the entelechies of Driesch.[2] These he calls dominants or higher energies. They are not subject to the laws of matter, are metaphysical, unconscious, yet psychic. Each smallest vital part has its dominants and they give all regularity and are revealed to us by the changes they cause in structures. The latter they may find ready-made by earlier dominants. They are also higher dominants of species, and

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[1] Johannes Reinke: Die Welt als That. 4te Aufl. Gebr. Paetel, Berlin, 1905. Einleitung in die theoretische Biologie. Gebr. Paetel, Berlin, 1901, Philosophie der Botanik. Barth, Leipzig, 1905.

[2] Hans Driesch: Der Vitalismus als Geschichte und als Lehre. Barth, Leipzig, 1905.

soul is their sum in the individual. God did not create one primitive cell only as Wiegand thought, nor one for each stem, but they are all from, and closely related to, pervading cosmic intelligence. Weismann's germinal selection he calls the Indian summer of Darwinism, whose winter is at hand. As opposed to evolution, he thinks bacteria may be regressive forms, apes, degenerate men and apogamy may arise from sex. His view is in sympathetic rapport with the conscious teleology of August Pauley [1] and with the action according to a purpose without consciousness of a purpose which Hartman [2] pleads for in this field.

Cope [3] calls the organizing force which makes life out of dead matter bathmism and the first unit it produces a plastidule. Anagenesis is the way up and kinetogenesis is the development of organs by movements and tendencies to move. He holds, as does Orr, that habitual acts have a morphogenic function. Katagenesis is retrograde development. Some plants are degenerate protozoons. The first most elementary phenomenon of life is rudimentary consciousness which has attended, if it did not direct, every step, *e. g.*, the development of the heart and intestines and their movements. But every function strongly tends to lapse to automatism and mechanism which is more simple and stable. Thus unconscious memory is basal and ontogeny or diplogenesis is motivated by this fallen but potent memory of the stages of the development of the race. Life is thus energy directed by sensibility or by mechanism that it originated. The beginning was energy becoming conscious, and consciousness having performed its part lapses into habit, function and structure.

Zehnder,[4] starting from purely physical and chemical principles, thinks that the lowest and first life unities are molecules, arranged in tubes or fistellæ, from rings, of which there are millions in the plasm of every cell and which are specialized so that some effect endosmosis, some contraction, others conduction, etc. Each tends to produce another like it and so they double rapidly. They are of different sizes and complexities, Their vortical shape make them permeable for atoms and even molecules which pass through their centre, and this accounts for absorption, swelling and growth. They expand and con-

[1] August Pauley: Darwinismus und Lamarckismus. Reinhardt, München, 1905. Especially Chaps. XI and XII.

[2] Eduard Hartmann: Das Problem des Lebens. Haacke, Bad Sachsa, 1906.

[3] E. D. Cope: The Primary Factors of Organic Evolution. The Open Court Pub. Co., Chicago, 1896.

[4] Ludwig Zehnder: Die Entstehung des Lebens. J. C. B. Mohr, Tübingen, 1899; and Das Leben im Weltall. J. C. B. Mohr, Tübingen, 1904.

tract, but this oscillation is about the constant size and this is the *Anlage* of muscularity. They are, nevertheless, essentially crystalline. Arranged in rows, often with conical ends, they constitute cylinders, contain fluid, and form these simplest tissues, in a square millimeter of which there are about 1,000 milliard fistellæ. No other structure can give such stability. Conductivity once established, psychic life begins, the early evolution of which he traces in some detail. The stellar universe is a larger and analogous vital organism.

Hatschek[1] finds two elementary processes of life, both due to rhythmic or phasic constitutional changes of biomolecules. One is generative and causes increase by division and rejuvenation, and the molecules that regulate these processes are termed generatules. The other is nutritive, regulated by ergatules which are working molecules. The former may change into various kinds of the latter, and, as they contain chemical radicals for all ergatules, they determine their nature, and hence, indirectly, all the properties of the body. The generatules are far more alike, but may change, especially where they are most numerous in the nucleus. The ergatules are very diverse and abound in the body of the cell. Their different kinds are distributed by division to the cells of different tissues according to the functions of the latter. They are derived from primary ergatules which are less differentiated. Outer influence can act on the generative substance in the chromosomes, not directly but only through the ergatules, which are nearest the germ plasm, and receive and transmit the net resultant of them chemically to the germ. This influence of the environment is effected by splitting off still smaller molecules called ergatines (after the analogy of antitoxines) and these directly effect changes in the composition and architecture of the generatules, which cause variation. Primordial vital substance had only generatules and, hence, could only multiply without many phasic processes of growth, and its biomolecules were quite likely far smaller and simpler than those of higher forms of life. As the body develops from one cell, so generatules and later ergatules are always evolving and organizing themselves into cells.

Semon[2] develops in a very able book a psychic primordium. If a stimulus, when it has ceased to work, leaves an after effect upon an organism that persists, this change is called an engramm, and the sum of all inherited and acquired effects in a special line is called a mneme. The simplest bit of living mat-

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[1] Berthold Hatschek: Hypothese der Organischen Vererbung. Engelmann, Leipzig, 1905.

[2] Richard W. Semon: Die Mneme als erhaltendes Princip im Wechsel des organishen Geschehens. Engelmann, Leipzig, 1904.

ter, and also all tissues are receptive, but the nervous system is specialized for the engraphy of mnemes. These processes, like many others, are best studied where the division of labor among cells is most developed, because here functions are simpler and clearer than in rudimentary forms of life. Thus the higher is the key to the lower. When two sequent stimuli are often repeated the first may come to produce the effects of both in the organism, and this is eckphoria, which later and introspectively we call association. Both engraphic and eckphoric effects may be caused by fainter and fainter stimuli and then some may act automatically as habituation in response develops. There are also latent effects observable only after the summation of many stimuli. Chronogenic eckphoria underlies and explains seasonal changes in plants and animals, such as ovulation, migration, etc,, while phasogenic eckphoria is the influence of a certain stage of development, like, for instance, puberty upon other changes set up by it, each stage of growth, *e. g.*, stimulating the next by means of the engramms of the race or species in each individual. Thus engramms persist through generations which are phasic repetitions of them and their combinations. The instinctive but adapted actions of young and lower animals are due to masses of inherited engramms. Weismann[1] criticises this theory, which he terms "brilliant and *geistreich*," because, unlike his determinants, engramms do not originate in the germ plasm only but in the soma as well. The engramms of the germ plasm are toned down images of the experiences of the rest of the body, transmitted to it from its various parts, and which become effective at each stage. Engramms are ever pressing germward from every organ. Semon does not know how, but collects many facts which he thinks show that they do so, such as the persistence of a daily rhythm in plants developed from the seed in constant darkness, or in plants transferred from north to south, or *vice versa*. Thus Semon's view is almost the polar opposite of Weismann, since, in fact, everything for the former is the result of the acquired experience of the individual or the race registered upon germ plasm. Upon this view memory is made the key to heredity and also to the states and processes of the "upper consciousness," which must also be explained, although in doing so we must sedulously avoid all terms of introspective origin.

While the above are the more important theories of their type, it may be interesting to résumé from my notes a few similar hypotheses which are either older or less elaborate.

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[1] A. Weisman: Richards Semons Mneme und die Vererbung erworbene Eigenschaften. Archiv für Rassen und Gesellschafts-Biologie. Jan. and Feb., 1906. 3 Jahrgung S. 1-27.

Among these we must place Bechamp's[1] ingenious microzymas which are of very different sizes, normally spherical, although they may temporarily take on different forms when closely apposed to each other. Their chemical composition is different and they may undergo specific changes in new conditions. They only really live, and death is the disaggregation of their temporary associations. Yet they cannot die but live on ready for new combinations, and in this form they pervade all earth and sea. God created them. Their chief power is to secrete soluble ferments. This action is essentially dissolutive and they evolve products of decomposition. They strongly tend to associate into organisms of ever higher order. Their lowest amorphous aggregation is glaivine in mother of vinegar, wine ferments, and next higher, in bacteria where they fuse into colonies of chaplet and other form, and third they make cells. Darwin's gemmules move about and penetrate all parts of the body until they reach just the right cells. Each represents the cell in which it arose and they give to the cells they inhabit the power to reproduce themselves. There is an incessant fecundation of cells by gemmules, but only germ cells receive gemmules of all the cells (pangenesis). Outer impressions tend thus to be reproduced in the sex cells, so that these change with the conditions of life. As growth progresses each new cell at birth receives more of the gemmules destined for it. It is, however, proven that gemmules are not transported in the nerves or in the blood, so that the weak point of this theory is how they so freely permeate the body. Hertwig's[2] idioblasts are bits of nuclear hereditary substance that grow and multiply primarily without otherwise changing. They represent all the elementary properties of the cell, each receiving not only just what it needs individually, but, as it were, sparks of all sorts of other ideoblasts that are characteristic of the individual. Some are active in some cells and some in others, according to the environment. In reproduction they fuse and do not juxtapose so that offspring are intermediate between the parents. In each there are dormant all the traits of the race, any of which another environment might have developed. Thus evolution is epigenesis or due to impressions made by different experiences upon originally identical material. Hence his view is opposed to that of preformationists like Weismann. Wies-

[1] A. J. A. Bechamp: Les Microzymas dans leurs rapports avec l' heterogenie, l'histogenie, la physiologie et la pathologie. Lille, Paris, 1883.

[2] Wilhelm August Oskar Hertwig: The Biological Problem of To-Day: Preformation or Epigenesis? translated by P. C. Mitchell. W. Heinemann's Scientific Handbooks, London, 1896.

ner's[1] plasomes are also the smallest vital particles that can reproduce themselves, for that is the cardinal biological function, although they must also assimilate and grow. We cannot tell whether they are eternal or spontaneously generated or whether each has a psychic element. Constituting everything that is alive, they differ immensely from all that is not so. They tend to mass and thus increase in size by intussusception. Most die, but not the gemmiplasm which persists and is little influenced by the environment. This is chiefly a growth theory and little more than that. Haacke[2] thinks that under polar forces living matter tends to crystallize into gemma and these plasm crystals into gemmairs. He gives geometric cuts of groupings, and between these forms and those shown in the cell during its development traces resemblances. The arborizations and other forms these elements take are explicable by the law of equilibrium which is to them self-preservation. Although there is an impulse toward perfection, biology is hardly yet an independent science. Verworn's[3] biogens are living molecules formed, after the analogy of chemical compounds, from lifeless matter. They are permanent, although their composition is ever changing, and are thus comparable with the flame of a candle. They have great power to leaven all that they reach with life by catalysis. These enzymes, as with Ostwald, control digestion, reproduction, and are a kind of energids that accelerate oxidization, Many of them are coordinated and highly specialized in each cell. Maggi[4] starts with amorphous glia which corresponds with Haeckel's unindividualized autoplasm. It is made out of organic matter and from it are first differentiated plastids which are free like bacteria, but which later became associated in monera and yet later combine into vital granules. E. Giglio-Tos's bionomes[5] are vital units which combine into biomads and then into cells. Jäger long ago thought that all dermal and glandular emanations either were, or were very closely connected, with ultimate germinal particles, and spent great ingenuity through two large volumes in working out the relations between sex and smell.

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[1] Julius Wiesner: Die Elementarstructur und das Wachsthum der lebenden Substanz. A. Hölder, Wien, 1891.

[2] Wilhelm Haacke: Gestaltung und Vererbung. Chr. Herms, Leipzig, 1893. See Die Träger der Vererbung. Biol. Centralbl. Juli, 1893. Bd. 13, pp. 525-542.

[3] Max Verworn: Die Bewegung der lebendigen Substanz. G. Fischer, Jena, 1892.

[4] Leopold Maggi: Protistologia, No. xxxiv of the Manuali Hoepli-Serie scientifica, Milano, 1882.

[5] Ermanno Giglio-Tos: Les problemes de la vie. Cagliari, chez l'auteur, 1900-1905.

From Plato's *nous* to von Helmont's *archæus*, animistic theories ruled all attempts to explain life, and later the great school of Montpellier gave wide currency and momentum to theories of vital force. The spermatists and ovists then long divided the allegiance of thinkers. After the microscope opened a new world and chemistry had proven the existence of bodies far beyond its ken, the scientific imagination took flight in micromeristic constructions, some of which, as we have seen, have been brilliant and stimulating in the highest degree. These invisible wonder-workers, if they exist, are the artists of life, older than all fauna or flora, and their remoteness in time is hardly less impressive than their special minuteness. Whether they are mind stuff or real things, they show that man's psychic powers can vie with nature herself in producing marvellously intricate structures, and they make a certain æsthetic as well as logical appeal to the mind. Some of them are wrought out with amazing cleverness and with immense labor and have great explanatory value, while others are cheaper products, but all shed new light upon the categorizing instinct of the human reason, and contribute something to realize the richness, worth and immemorial antiquity of life and of the soul, henceforth one with and inseparable from it.

All the above views transport the most basal and interesting problems of both life and mind to the inconceivably remote in time, small in size and to matter, whether conceived materially or dynamically, till they seem tantalizingly transcendent and the field of ordinary experience appears cheap and rude, a kind of reliquary of nature where and when she was in her creative prime. What used to be called brute matter, for which thinkers have been almost misophobiac, now seems nearer the great first cause, full of far more possibilities and potencies than have been realized, and so much above and so far more complex than mind that science cannot even understand it. Perhaps now, with the marvellous new views of the ultimate constitution of matter, we exalt rather than degrade the soul and life just in proportion as we explain them by physical and chemical forces. Reason is not adequate to grasp these, and our cleverest thought and imagination only formulates our ignorance and is less, not more, than fact. Matter seems more than life, life more than mind, and germ plasm far beyond the power of the brain or soul to comprehend it. Mechanism is most and life the least knowable.[1] We cannot know self in any fundamental sense till we know protoplasm or the amœba, and evolution is only the best case of devolution. In this new orientation and trans-

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[1] Konrad Guenther: Darwinism and the Problems of Life, tr. by J. McCabe. Owen, London, 1906.

valuation, it is the undevout materialist and germ-plasmist who is mad, and even dissolution and death lose some terror and acquire some charm, for we are in the end at least resolved soul and body into some diffusive powers, which are the "mothers of life." Which way really lies up and down, progress and retrogression in the vast continuum we call the universe, but which may have no boundaries or breaks in either time or space? Again, the inveterate fallacy of students of the soul, with the exception of a few bolder spirits mentioned above to explain everything by the nearest cause, is in striking contrast with the tendency of biologists to utilize the new horizons of distance and size, although, save the few who accept Weismann's[1] biophores and determinants, almost none of these have followers. As we know it chiefly in cells, protoplasm is no longer primal, homogeneous or structureless, but is pervaded, if not constituted, by a slowly accumulated mass of heredity, with thousands of latent traits, for to live is to habituate. Their momentum still dominates and all that has followed since is relatively easy and brief. Every bit of protoplasm has a long history, or is, in fact, an historic structure, and trophic and reproductive primordia still impel to variations that are independent of present utilities or of recent environment. From these phyletic structures assimilation and dissimilation, growth and reproduction, the most fundamental traits of life, the bases of hunger and love, arose before the oldest fossils, so that their pedigree is lost.

Geike[2] puts the formation of the solid crust of the earth at little less than 100 million years, shortly before the seas were developed and the plankton on its surface, where Brooks[3] thinks life evolved, was formed. Joly[4] thought 55 million and Dubois 36 million years the probable time since river beds began, and Lord Kelvin,[5] in 1862, estimated from the rate at which the earth's crust cooled that nearer 20 than 40 million years must have elapsed, and many estimates of increasing temperature downward must have approximated this calculation. George Darwin[6] concludes that the moon broke away from the earth some 56 million years ago. How can we reconcile the fact that the first life was doubtless aquatic with the chiefly igneous nature of the oldest rocks. I can only suggest that perhaps the convulsions caused by the breaking away of

[1] August Weismann: Essays upon Heredity. Clarendon Press, Oxford, 1891-92.

[2] *Opus cit.*, p. 153.

[3] William Keith Brooks: The Foundations of Zoölogy. Macmillan, New York, 1899.

[4] *Opus cit.*, p. 153.

[5] *Opus cit.*, p. 153.

[6] *Opus cit.*, p. 153.

the moon from the volcano-girt Pacific, which Pickering thinks occasioned the Americas to split from Europe and Asia, the general contours of which are so conformable, made the oldest rocks so metamorphic that in the heat and the mixture of their semi-moulten magna all the earliest records were obliterated. This would explain the fact that, when the crust petrified and the earlier clear palæontological traces were laid down, we have so early so nearly all of the great branches of the animal kingdom, although the highest are represented only by their lowest and most generalized forms, especially in the case of vertebrates. Despite this cataclysm, some of nearly all the then existing species must have survived in some locality as in a veritable Noah's ark. If, as de Vries[1] thinks, species arose by mutations, and these in early times were greater, in more directions and with shorter intervals between their periods, the geologic time available might more easily suffice, while a longer period would be required if variations were very gradual.

It is a common view that the lowest organisms are most persistent and least variable and that many of them have not changed since the first appearance of life, but have continued to breed true to their primitive type. Weismann, Poulton and Darwin held this view. The latter was "sorely troubled" at Lord Kelvin's limitation of geologic time and would have preferred Fry's estimate[2] of 2,700 million years since life began, the assumption being that evolution started very slowly and was accelerated as it advanced to higher types. But, instead of being most rigid, should we not rather regard these earlier forms, when heredity was, as it were, young and had not acquired its momentum, as most plastic and least stable, as more are now coming to think. This view Bastian[3] has lately wrought out with great boldness and ingenuity. The apparent persistence of simplest forms he thinks due to incessant *de novo* production from non-living matter, just as crystals arise wherever conditions are fulfilled. Instead of being Silurian, countless ephemeromorphs are always arising, a peculiarity of their molecules being to take on life forms. These are ever arising in great profusion by archibiosis. The lower of them are heterogenic and pass into each other by transformation where *per saltum* variation may even cause a rotifer's egg to develop into a ciliated infusoria. To this class of cases much of Bastian's book is devoted. When we conceive an atom as the core of a

[1] Hugo de Vries: Die Mutationstheorie Veit. Leipzig, 1901.
[2] Sir Edward Fry: The Age of the Inhabited World and the Pace of Organic Change. Monthly Review. December, 1902, Vol. IX, pp. 42-53, and January, 1903, Vol. X, pp. 68-83.
[3] H. C. Bastian: The Nature and Origin of Living Matter. T. F. Unwin, London, 1905.

group of positive electrons, like a sun, around which negative particles revolve in orbits like our planets, and an atom of hydrogen as different from one of iron, *e. g.*, only in having more planets or different orbits, so that new elements like thorium, uranium and perhaps helium are undergoing spontaneous generation, why, asked Bastian, should we deny mutability, plasticity and spontaneity to the vastly more complex foramenifera? Rapid and immediate response to changed environment, with the influence of the past less and that of the present greater, causes in low forms of life alterations that seem fitful and lawless, but these preform the discontinuity of variation and the mutation which Bateson and de Vries find in higher forms. Both are leaps across perhaps not yet well settled taxonomic demarcations. This, too, would account for the universal distribution of simple forms. The similarity of old and new types is due to like conditions. Bacteria may occasionally arise spontaneously, so that not every germ disease is due to contagion, and so may some torulæ and molds. Links of relationship that unite organisms are therefore not all hereditary, but are partly due to uniformity of laws acting under uniform conditions, or to constant matrices which are ever fertile. Of these ever upsurging new forms the highest animals arose from oldest, man with his brain and reason being very likely as aberrant and transitory as the monstrous reptiles of the Trias and Jura, the beginnings of the far higher forms that will supersede him being perhaps in the act of arising from matter to-day. Finally, Bastian agrees with Newcomb that among all the countless stars there must be "thousands and perhaps millions" on which the conditions are so like those on the earth that life surely exists, though doubtless different, in some worlds higher, in others lower, than here, but in all different.

If the way up to life, being once found, is still kept open and is still traversed as much and even as slowly as at first, this, of course, does not affect the view that its original construction was long and hard. There may be many ways and those now used may short-circuit the old ones, or the best may be selected and all the old ones discarded. New plasm may be formed by rapid recapitulation of the mode of origin of the first. Protoplasm must be of innumerable kinds and compositions and the new, although undistinguishable from the old, may be essentially different and without all its promise and potency. The first plasm may have exhausted itself in giving birth to the higher species, and the persistence of low ones may be due to progressive incapacity of nature to equal her first effort, so that when the higher forms have vanished only attenuated, abortive and ever simpler ones will be left, life as a whole dying from the top downward, as old men produce ever less effective sperm.

The power to breed true may decay and only late and novel forms may transmute, indeterminate heterogenesis marking decay at the root; or, conversely, life in the far future may be more vital and both the plasm and species of to-day be the products of nature's prentice hand, so that the phylogeny of the future will recapitulate that of the past with a much increased rapidity and economy as the individual recapitulates the history of the race, perhaps even higher species transmuting into others. Dreameries like these do not begin to exhaust the speculative possibilities in the field where so little is known, so much is possible and the hunger for new light is so great. More seriously we may ask how, if life is ever arising anew, we can explain the law of both palæobotany and palæozoology that if a species dies out it never reappears in a later geologic age; also the fact of life-zones and of the disparity between homotaxy and contemporiety, now well accounted for, would be harder to explain[1] than if all existing protoplasm is derived from previous protoplasm and is now so complex that its present form must be the result of a very long period of development since it first became protoplasm.[2]

Plants, says Fechner,[3] might well ask whether restless human bipeds were of any use in the world save to prepare carbonic acid for their leaves and when they die to furnish with their rotting bodies nitrogen for their roots. Plants eat, spread and fertilize their seeds, and insects are only love messengers to bring pollen to the female blossom. The plants could exterminate the humans by sending forth a bacterial army. Fechner was led to postulate souls in plants as one result of his conviction that the psychic elements of individual life could be preserved after death in a high unity. Indeed, under all physical processes he assumed a psychic rudiment which must cross more than one threshold to become conscious, so that there must be a psychic corresponding to the physical continuity. Fischer[4] thought the word "*eidos*," idea, meaning form, suggested that there is something psychic in every organization of a type or species which is comparable to a school of art or philosophy. Motion had no beginning and is the life of the world, and rocks and earth are a cadaveric rigidity after the secretion of which protoplasm is left over. Life is persistent, not gener-

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[1] H. Nichelson and R. Leydekker: Manual of Palæontology. 3rd ed. Blackwood, Edinburgh, 1899.

[2] O. Hertwig: The Cell. Tr. by M. Campbell. Macmillan Co., New York, 1895.

[3] G. T. Fechner: Nana oder über das Seelelenben der Pflanzen., 2 te Aufl. Mit eine Einleitung von Lasswitz. L. Voss, Hamburg, 1899.

[4] Fischer: Ueber das Princip der Organization in der Pflanzenseele, 1893.

ated, but sprang from the absolute basis of all being where it existed in potentia so that there never was a time when all the world was dead, and plant souls are the summation of molecular souls. Némec[1] thought he had demonstrated structures and functions in plants not unlike those which Apathy found in the higher metazoa. He concludes that many vascular plants possess special structures for conducting stimuli in the cytoplasm of their cells, so that the similarity to like processes in animals is far closer than had hitherto been supposed. After demonstrating structures that seemed homodynamic, his conclusions were confirmed by studying experimentally the propagation of stimulus, and this indicated fibres set apart for this purpose, for their bundles could be followed directly to the seat of the bending movements, and both fibres and the function of quickly responding thus vanished again. He finds just under the dermal surface of the root cells sensitive to geotropism, and these cells are characterized by the presence of grains of starch which serve to orient the root to gravity. Their specific weight is greater than that of the protoplasm of the cell, so that they press against different parts of the surface in different positions of the root. The stimuli is transmitted with undiminished intensity, and in some plants these movable starch grains are developed to a special organ comparable with the static organs, which in metazoa are provided with statoliths. This author agrees with Czapek that there is no difference in principle between many reflexes of plants and those of animals, and that not all movements of plants can be regarded as antetypes of metazoan reflexes.

Before and especially since Darwin showed the adaptive movements of plants, their many modified forms of circumnutation in epinasty, hyponasty, nictetropism and sleep, their sensitive responses to light, heat, gravity, moisture, contact, etc., compared their movements to those of animals, the tip of branch and root to a brain, studied their cunning devices for catching and digesting insects, their reactions to their visits in cross-fertilization, and their plasticity under domestication, botanists have applied many experimental methods and measurements which show that if plants do not have a soul, we need only to magnify their movements in space and condense or accelerate them in time to see that their motor reactions give them an exquisite rapport with their environment, which is as good as, if not better than, psychic. The brilliant and epoch-making experiment of Bose[2] goes much further and

[1] Dr. B. Némec: Die reizleitenden Strukturen bei den Pflanzen. Biol. Centralblatt, June 1, 1900. Bd. 20, pp. 369-373.

[2] Jagadis Chunder Bose: Plant Response as a Means of Physiological Investigation. Longmans, Green & Co., London, 1906.

shows that there is no important reaction of the most highly organized animal tissue that is not also found in plants. Their motility under electrical and other stimuli is not confined to young plants, buds or leaves, but they are very sensitive to fatigue, which has its curve of excess and recovery. Every stimulus has its latent period, its threshold, its optimum conditions, and may be summated into actual tetanus. Plants are sensitive to many drugs. Alcohol exalts or depresses their functions as it does those of higher animals. Some have sense organs that can be located. Many of them pulsate with waves of turgidity and with regular, though usually rather slow, systole and diastole and thus they circulate sap. Plants may be killed, although not without a marked preliminary death spasm with subsequent *rigor mortis* followed by relaxation. They die more easily if fatigued. The rate of transmission of a wave of stimulus is measured. Sap rises from the root to the highest tree top not chiefly by capillarity, but by active suction, also measurable by special apparatus. Growth is rhythmical, consisting of a wave up and another back, the real growth being the excess of the first over the last. Plants can be habituated after a refractory period. Their sleep is caused not by darkness, but by real exhaustion. Their tropisms to sun, earth, currents, their power to twist and twine is affected by age, previous activity and many other circumstances. Excitation is transmitted from one part of the plant to another by lines of protoplasmic reaction, along which the stronger the stimulus the greater the velocity. In both plants and animals the anode blocks transmission and most motile response is all or none, as with the animal heart, while acids and alkalies have an action quite akin to that of the heart. In all these reactions there are characteristic differences between species, old and young plants, and sometimes between individuals of the same kind and age. Even the author's experiments with such common plants as celery and lettuce show a behavior in them that can hardly be entirely excluded from psychology. Thus the unity between plants and animals is fundamental and detailed. Everything in the latter is at least begun in the former so that experimental psychology must henceforth have a botanical section. All is vital and yet all becomes mechanical in proportion as it is known. The general order of phyletic development in the plants was first algæ or perhaps fucoids, then acrogens, conifers, cycads, palms, with phænogams and their fertilizing insects late, and it would be an interesting next step to know how the physiology of early and late plants compares. It is only because our studies of the mind have been so chiefly human, adult and analytic of the consciousness of the present moment that they are too provincial to see the ocean of soul of

which our mind, which we think is so supreme, is but one outcrop, or that we find it so hard to realize that upon any large and sound definition of soul life, more of it existed and perished before man appeared than all that has arisen since. Wherever there is vitality there is *psyche*, and science not only shows nothing to contradict this deep instinctive belief that crops out in animism in all primitive religions, in poets, ancient philosophers, is imbedded in the structure of language, myth and popular opinion, but plants show not only what Aristotle called the nutritive and reproductive soul, but add to these subtle responses to all the influences of their *milieu*. The psychic life they show is the oldest and most dominant part of the soul in our narrower sense of that term and here, therefore, we must find the apperception organs for all the rest of our knowledge of the latter. Man's secondary consciousness is only one of the countless allotropic forms of soul, although even it may by an act of faith be postulated as but one of the many forms of energy sometime to be explained under the law of cause, and all perhaps quantitatively. Just so far as psychology becomes a natural genetic science it will trace all higher powers back to those we have in common with plants and the simplest animal forms, and *vice versa*, derive all the former from the latter.

The earliest plant life was very abundant, but of few kinds, and those so perishable that palæontological traces are rare. Indeed, vegetation has been chiefly terrestrial and its marine forms low in type. The simplest of these are very plastic and can subsist in water, hot or cold, saturated with salt, lime, sulphur, silica, and about everything soluble. Some can endure freezing and great desiccation. Bacteria, though derived and not original forms, must have existed to account for decomposition. The peat mosses and then the ferns and equisetæ, lycopods of the coal age, and later yet the seed plants or spermatophytes on which animal life is most dependent for food, was the order. As opposed to the common view, some now hold that life originated on land and in fresh waters and migrated to the sea. Despite his control in agriculture, plants have done a vastly greater geologic work than man and are far more plastic to diverse conditions than are animals. The latter is doubtless especially true of the first forms of which so little is known. While it is unsafe to infer from the responses of the very high and sensitive plants of tropical India, with which Bose found his most striking results, to primitive plants, the botanical realm probably shows no exception to the general rule, true also for zoölogy, that the responses of lower forms of life are relatively more in structure and those of higher forms in function.

Every detail in both the life and form of every plant is due to stimuli from its morphological environment. Heredity is the innateness in the individual that was acquired by the species. Probably all these structural and functional adjustments to conditions were originally compulsory. Inflorescence, *e.g.*, is the condensed result of a slow modification of leaves into petals, each stage of which had some external cause. Reproduction and all its intricate stages, types and attendant phenomena was impressed item by item upon substance endowed with two traits alike marvellous, viz., plasticity to receive and persistency to retain. Growth, size, shape, texture, position of leaves and buds, color and every other item which distinguishes one species from another, are one and all the accumulation of what were primarily individual reactions to light, temperature, moisture, chemicals in air and soil, contact, gravity, etc. All differences in plant structure are massed effects or records which science must read of the way and degree these forces have acted upon them or their ancestral forms; hence, to know plants completely is to know their history. In other planets where these incident forces were differently composed or proportioned, plant nature would be changed exactly as much but no more than they. Moreover, an individual life is not the unity it seems, but an aggregate of units, or, as Bateson[1] calls them, allelomorphs, which are often of very diverse origin, independent one of the other, but which in reproduction may be combined in every possible way. While in old established forms acquired qualities modify heredity only very slowly, so that Weismann is essentially right that the net results of individual life upon germ plasm are minimal or naught, the past determining everything, only Lamarckianism in its most extreme form can explain the evolution of races, species and their every diversity, great and small. Hence, preformation theories lack chronological perspective in the same way, though in less degree, than does creationism itself. If every change from fertilization to maturity is dependent upon a series of stimuli, instead of being spontaneous as extreme experimental embryologists think, then all the

[1] "Each such character, which is capable of being dissociated from or replaced by its contrary, must henceforth be conceived of as a distinct *unit-character*, and as we know that the several unit-characters are of such a nature that any one of them is capable of independently displacing or being displaced by one or more alternative characters taken singly. We may recognize this fact by naming such unit characters allelomorphs. So far we know very little of any allelomorphs existing otherwise than as *pairs* of contraries, but this probably merely due to experimental limitations and the rudimentary state of our knowledge." W. Bateson: Mendel's Principles of Heredity. University Press, Cambridge, 1902. p. 27.

more must this have been true of the development of species for which stimuli must have been relatively more and response slower and more uncertain. From this new view point psychology must henceforth study all structural and functional adjustments as the key to all perspective and reflective adaptations. The moving equilibrium that pervades animate nature differs from human intelligence in nothing fundamental save that in the former new adjustments to new influences in the environment are slower in time. What we call consciousness is derivable from the suddenness or the biometamorphosis with which new balances are attempted and attained and to the more complex and manifold changes that this involves in higher organisms which are susceptible to shock in a different way. Thus the genetic psychologist may regard man, as von Baer has suggested, as at bottom a vegetative being (most of his organs concerned with metabolism, circulation and reproduction arising from the entoderm on which is superposed an animal or psychomotor being, the senses and brain and, to at least some extent, the muscles, arising from the entoderm).[1] In some sense we may speak of latent mind in vegetation or of life as nascent mind and mind as patent life and in so doing lay a new fillet of wool on the creations of Schelling, Fechner and even Bruno. and admit that speculative sagacity and even oriental pantheism, like that which animates Bose, are not to be regarded as *a priori* anti-scientific.

Of the early pre-Silurian animal ancestors of man from unicellular protists up to the oldest skulless, jawless, limbless monorhine vertebrates, Haeckel makes fifteen progonotaxic stages, of all of which palæontology shows no trace, although each has living relatives. He admits that other pedigrees might be made, although for some he expects further knowledge to verify his hypothetical forms. In the oldest Archæan age, of which, if we accept the planetesimal theory, there can be no assignable lower limit, although there are no fossils, there is evidence that life was abundant, while little is known of its character and it is separated from the next age by a great unconformity, as is the next or proterozoic age from the palæzoic, where abundant fossils are first found. It is believed that the earliest were algæ, rhizopods, infusoria, plastoid, with multicellular hollow vesicles. Later came gastrula forms with two germ layers; then primitive worms of an ascending order, ending with those that showed anticipations of a notchord, and then the low skulless vertebrate. During this period the intestinal cavity, a respiratory tract, which was first in the gut

[1] Ernst Haeckel: Evolution of Man. 5th edition trans. by J. McCabe. Putnam, N. York, 1905. 2 vols.

itself, renal functions and the flexible axis between the intestine and a ganglionic chain which was the *Anlage* of the spinal chord, were developed. Of course Haeckel abhors the inverted evolution of Dohrn,[1] who has himself since repudiated it, that the amphioxus, thought to be the parent of all vertebrates, was a degenerate cyclostome, that even ascidians and tunicates are decadent fishes and that all animals are the progressively fallen offspring of man who was at first sole and supreme. He thinks the tunicates, although degenerate, are the nearest blood relatives of the vertebrates, although only from a common root and not in their line of descent. There is no doubt that touch, smell, complex movements, rudimentary vision and taste were developed in the primordial sea before the age of the oldest fossils. Life histories, habits, reproduction, recapitulation by the individual of the traits of its race were established in a fundamental though very simple way, and movements that were adapted to needs and adjusted to stimuli were developed and concatenated.

It is even harder and more conjectural to select from the psychoses of living lower forms those traits that were near the beginning of the line of descent of man's mind than it is to trace this stage of the pedigree of his body. Probably the food quest is the first field of development of an individual *psyche* and this is often quite intricate in the protozoa. An amœba can squeeze an acineta to obtain the young from the ovarian aperture, which it seizes as soon as it emerges and ultimately digests. Paramecia gather about a bit of bacterial zoöglœa, show antipathy to alkali, troop about a drop of dilute acid like a crowd about a popular orator, maintaining an optimum distance where the intensity suits them, although they often seem to mistake bits of filter paper for food. Actinophrys watches for the spore cells of pythium as the ciliated monadic germs emerge, captures and devours them all. Actinaria wave their tenticles inward in the presence of soluble food so that Jordan[2] thinks they taste, Romanes[3] that they smell, Nägeli[4] that they are only stimulated muscular action, Loeb[5] that the ciliary surfaces are also, if not chiefly involved. Parker[6] shows that

[1] Anton Dohrn: Das allgemeinste Gesetz der Natur in alles Entwicklung, 1864.

[2] David S. Jordan and Vernon L. Kellogg: Animal Life. D. Appleton & Co., New York, 1900.

[3] George J. Romanes: Jelly-fish, Star-fish and Sea-urchins (International Science Series). D. Appleton & Co., New York, 1885.

[4] Carl von Nägeli: Mechanisch-physiologische Theorie der Abstammungslehre. R. Oldenburg, München and Leipzig, 1884.

[5] Jaques Loeb: Vorlesungen über die Dynamik der Lebenserscheinungen. J. A. Barth, Leipzig, 1906.

[6] T. Jeffrey Parker: Lessons in Elementary Biology. Macmillan, London, 1901.

in some kindred forms the waving of the lip-cilia caused peristaltic gullet contractions of the sphincters of the oral disk. Hodge[1] thought that vorticellæ, after filling up with yeast torulæ and violently disgorging them when found unfit, learned to avoid them. Some phenomena ascribable to thigmo- and chemo-tropism and even to ions are really due to the food instinct. This primitive hunger cannot, yet, at least, be explained as endosmosis or as chemical affinity between the animal body and its food as Dantec suggests. If the psychologist can say of any element of the soul that it was first, it is something which has developed, through we know not how many stages from some such germs as the above illustrate, into appetite, and this has ever since been one of the most potent springs of mind. It is perhaps not only the oldest but the strongest of all ontologic impulsions and involves some discrimination of touch-taste or of smell or both, as well as some differentiation between the euphoric state of satiety and the painful one of incipient starvation. The mode of getting food first differentiates animal life as mobile from plant life as sessile, so that here the genetic psychology of the individual takes its rise. It is at first about the only content of the infant soul and gives shape to nearly all forms of animal life in the struggle for survival. The first formula of will in the zoölogical world is, "I would assimilate and raise this or that to the plane of my somatic life and so grow." Perhaps when we know why one thought or feeling is preferable to another it may sometime be clear that it is at bottom because it favors cerebral or general nutrition. An animal is a creature that seeks its food by active movements of the whole or a part of its body and it is at home wherever it finds it.[2]

Another primitive motor orientation was probably caused by light. This, of course, began long before any rudimentary eye and is seen even in bodies that appear to us transparent. As early as 1878 Strassburger[3] showed that certain plant spores moved toward light at a rate determined by its intensity. Some twelve years later similar tests began to be made on lower animal forms and of such studies there is now a copious literature. Loeb[4] found that rudimentary organisms either gathered in light of a preferred intensity or parallelled the axis of their bodies to

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[1] C. F. Hodge and H. A. Aikins: The Daily Life of a Protozoan. *American Journal of Psychology*, Jan., 1895, Vol. 6, pp. 524-533.

[2] For its paidological outcrop see Sanford Bell: An Introductory Study of the Psychology of Foods. *Ped. Sem.*, Mar., 1904, Vol. 11, p. 51-90.

[3] Eduard Strassburger and others: A Text-Book of Botany. Trans. by H. C. Porter. Macmillan, 1903.

[4] Jaques Loeb: Die Orientirung der Tiere gegen Licht: Sitzungs ber. d. phys. Ges. Wurzburg, 1888. S. 1.

the incoming ray, or both. In a box, one end of which is near a window and the other darkened, some forms gathered at the light end, some at the dark and some at intermediate points, as they are positively or negatively heliotropic. Verworn[1] and Altmann found an orientation to a certain intensity of light which they thought to be more or less psychic. Miss Towle[2] studied cypridopsa in a case covered with a glass prism filled with India ink, so that one end was dark and the other light, as Yerkes[2] did entomostraca, daphnia and other crustaceans, and all were found distinctly phototactic. Such creatures tend to move to and fro and settle in the light intensity to which they are attuned or accustomed. Some of them change from positive to negative response and they alternate between the two. Choice is often affected, as is the retina, by the degree of light from which the creature has just come. As to color, Burt and Lubbock[2] found daphnia preferred yellow and green, Engelmann[2] that navicula seemed to have preference in the following order: red, yellow, green, blue, violet, although intensity may be a more important factor than chromopathy. For some low orders of life it seems that the limit of susceptibilty at both ends of the spectrum is nearly that of man. Graber[2] found marked response to color in the simplest forms of life. Some of these earlier experiments did not sufficiently eliminate the heat differences of the different spectral colors, nor consider the movements and attitudes of the features to be tested with reference to the direction from which the rays came, nor did they determine the shock causable by sudden changes of light. But it is certain that eyeless, nerveless beings thought to be more or less like the very earliest human ancestors are keenly alive to light in ways not yet explicable photochemically save by theorists, as if some optical function were early diffused throughout the body. Light preferences may have been affected by the sea level to which the creature was accustomed and have been to some extent both cause and effect of its habitat. Perhaps, too, in palæozoic times the atmosphere made the quality of daylight, and possibly even night, very different from what it now is, but, although some amœboid forms of life seem to show little diurnal rhythm, for most grades of existence day augments and darkness depresses activity. It is not known that even this ancient change ever produced true ephemeridæ whose spontaneous life was limited to one day. Thus the chief time markers, day and night, early began to cadence life to their rhythm which has since developed into sleep and waking. Life entirely in the dark is probably derived and not original.

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[1] Max Verworn: Psycho-physiologische Protisten-Studien. G. Fischer, Jena, 1889.

[2] For complete reference see p. 212.

Hence a light appetency or hunger arose with optima more or less definite and specialized, and the phototropic eye of the new-born babe, like everything else, has its long ancient phyletic history of which we as yet know so little. Even light was probably at first ancillary to metabolism.[1]

Primitive organisms respond, some of them, very exactly to thermal stimuli, seeking the optimum of temperature most favorable to their life processes. Placed in troughs, one end of which contains ice, with a lamp under the other, they orient and migrate, settling where conditions are best. They can be acclimated in temperatures more or less different from all those to which they are wonted. They have their upper and lower limits above and below which vital processes are suspended. Contrast effects are produced by which those coming from colder environments seek higher and those from warmer seek lower temperatures; also habit effects by which they settle at points in the scale most nearly like those they have just left. Both these have their respective human analogues when men warm themselves after cold and seek coolness after heat and also find difficulties in adjusting to tropical or polar climates. Some are acclimated and others can adjust to far greater thermal extremes than man and some to less. Sympathy began with warm-blooded animals, and to keep their young warm is one of the primordial factors in parental care and love. The social instinct, too, as Sutherland has shown, is partly due to huddling for mutual warmth.[2]

Contact is the only stimulus that may be older than hunger, or the three states of matter, solid, fluid and aerial or gaseous, life doubtless began in the second, and it is conceivable that its haptic experiences may have been often limited to changes of pressure due to diverse rates of movement in water. Where thigmotic and stereotactic impressions occurred, they were with films, surface tensions, food, each other, or with enemies, and only rarely and later with shore, bottom, rocks, etc. The almost sole movement of a primitive group of simple forms, of which the paramecium is a type, is a forward push, then on meeting an obstacle a backward thrust, a turn to right or left at an angle dependent on the stimulus, with slight rotation of the body, and then forward again in a new direction, and the reaction is the same to chemical changes, surface, electric and

[1] For the outcrop of this psychosis in infancy, mythology, etc., see the author's study with Dr. T. L. Smith: Reactions to Light and Darkness. *Am. Jour. of Psy.*, Jan., 1903, Vol. 14, pp. 21-83.

[2] For the recrudescence of this ancient pyrotactism in children and its rôle in human life, see the author's study with C. E. Browne: Children's Ideas of Fire, Heat, Frost, and Cold. *Ped. Sem.*, Mar., 1903, Vol. 10, pp. 27-85.

other currents. For Spencer the primitive experience is a bunt and the first psychic progress consists, perhaps, of an incipient sense of light and dark, or in anticipatory touch, which is the mother of sight and all the other senses. Bottom creepers love crevices and may develop responses to points, curves, compression, changes of permeability, cohesion, thickening, etc. (aero-campo-tropism, taxis, kinesis, or peran-synaph-pachym-osis, etc.). Pressure changes not only in the oral end but in different parts of the body slowly develop reactions of different intensities and kinds as they are favorable or inimical to life in various degrees, and bodies are oriented along branches or edges squeeze into holes and cracks, hug against each other, cling as parasites, habituate themselves to thick or rare fluids, appose their bodies and attach their larvæ to certain forms or textures, distinguish food by its feel, are at home in certain, while oriented toward and perhaps exploring, greater or less densities, seeking or avoiding solids, etc. Such multifarious experiences with hardness are the psychogenetic basis of the very word "objectivity," and tactility is the root of reality. Hence, the epistemology that would subjectivise things into thoughts is only a grimace or affectation because what is fundamentally motivated by, and based upon, such manifold experiences of our eozoic ancestors through ages, compared with which all the time since man appeared is but a moment, cannot be eradicated by the decadent dreameries of speculators isolated from contact with actuality in artificial conditions of life.

Reactions to chemicals must have played an immense rôle when life was young and aquatic. Sedimentary rocks were once in solution, and in volcanic action, heat melted and dissolved them, far higher tides than now eroded them. The ocean may have been much like the Sargasso sea; it may have had salt, lime, silica, chloride of magnesia, potassium, and every mineral of the earth's crust, still found at least in small quantities, dissolved in it with every vegetable and animal substance. There were oozes and muds of diverse consistency on the way to become soils, and all these conditions made the cradle in which life in its infancy was rocked. Experiments with forms of life imprisoned in a drop and under a microscope slide, by Loeb, Hardesty, Garey, Nägeli, Dantec, Schürmeyer, Bokorny[1], showed them to be variously chemo-, tropo-, taxo-, kinetic, to be acutely oriented to oxygen, alkali, carbon, narcotics, and to water (alkalo-, aero-, oxy-, narco-, and hydro-tropic and phobic). Chilomonas enter but cannot get out from a mildly acid drop which acts as a trap, perhaps because the acid reduces their strength and they dispose themselves radially toward the top and respond to the stimulus of its partial desiccation by evaporation and if the acid is strong they may whirl until they

[1] For complete reference see p. 212.

die. Oxytricha swims into a dense solution which kills it. Chemical stimuli usually act on all parts of the body at once but in different degrees in different parts. Around diffusing acid drops, there are two invisible boundaries, an inner and an outer, and crowded within the neutral ring paramecia zigzag. If they are accustomed to an alkaline fluid to which they are negative in the culture jar, and then become attracted to an acid, or else are impelled to it by the neutralization of the alkali. When transferred to still water they are neutral to most chemicals and then resume their old sensitiveness. Massart found that increased measured osmotic pressure caused fluid to pass out of the organism and a decrease into it and that this stimulus caused motion. Carbon dioxide attracts it and yet they need to excrete it. Pfeffer thinks the effects on the outside of their bodies may be beneficial and opposite to the internal effects. In general, chemical influences underly every vital functions and pervade the entire physiology of life. Such phenomena as the above are far below restoration, yet are prelusive of it, are associated with each other and with the food quest and metabolism in ways not yet understood, and suggest some of the reverberations yet persisting in man of ancient pelagic influences[1] and that one day physiology, if not psychology itself, may be expressable in chemical formulæ and show in what close rapport water life originally was with the elements.

Even electrical phenomena now and probably from the first has produced motor and perhaps psychic responses in the lowest forms of life. Verworn,[2] Roux,[3] Wallengren,[4] Kahlenberg,[5] Ludloff, Loeb,[6] Pearl,[7] and Jennings[8] have sought to show various rheo-polo-galvano and electrotonic effects, orientation with the diffusion lines of ions, the reactions generally increasing

[1] Frederick E. Bolton: Hydropsychosis, *Am. Jour. Psych.*, Jan., 1899, Vol. 10, pp. 169-227.

[2] Max Verworn: Untersuchungen über die polare Erregung der lebendigen Substanz durch den konstanten Strom. Pflügers Archiv, 1896. Bd. 62. S. 445-448.

[3] Wilhelm Roux: Ueber die "morphologisschen Polarisation" von Eiern und Embryonen durch den electrischen Strom. Sitz. Bericht. d. k. Akad. d. Wissenchaft zu Wien. Math. u. Naturw. Classe, Bd. 101, pp. 27-228. (Ges. Abhandlg., Bd. 11, S. 540-765.

[4] Hans Wallengren: Zur Kentniss der Galvanotaxis. Zeitsch. der allgemeine Physiologie, 1903. Bd. 2. S. 341-381, 517-555.

[5] Ludloff: Untersuchungen über den Galvanotropismus. Archiv. f. d. gesamte Physiol., 1895. Bd. 59. S. 525-554.

[6] Jacques Loeb: *Op. cit.*, p. 191.

[7] Raymond Pearl: Studies on Electrotaxis. Am. Jour. Physiology, July, 1900, Vol. 4, pp. 96-121. Some Aspects of Electrotactic Reaction of Lower Organisms. Report of the Mich. Acad. of Science, 1901.

[8] Herbert S. Jennings: Contributions to the Behavior of the Lower Organisms. Columbia University Press, 1906. Macmillan Co., agents.

with their atomic weights of velocity. Some think these effects due to anions, and that they resemble those of acids, while others hold that the heavy metallic kations were prepotent. Some think the reactions of infusoria to electricity are different from those to other stimuli. Most hold this action to be cataphoric, causing the body to swell on the cathode side to which the fluids in the body are drawn. This is true of dead but perhaps in less degree of living animalcules. Paramecia are drawn backward toward the anode by a strong current while trying to swim in the opposite direction. There is a peculiar struggle between a contact stimulus and a constant electric current, the characteristic arrangement of the cilia in thigmotaxis being overcome for an instant then resuming its sway, then the electric condition dominating again. This orientation continues and the two stimuli do not give a resultant action, the cathode usually being more attracted than the anode.

Again mention should be made of geotropism and of changing specific gravity according to needs and at different stages of growth, and the depth at which the creature lives as Pratt, Davenport and Williams have shown.[1] The heavier the animal the greater the effort in swimming. It is hard for a mosquito larva to reach the surface, cypridopsis must move fast or sink, cyclops goes by jerks, sinking between each, and other forms hold themselves up by clinging with their antenæ to the surface film or to a solid object. Others regulate their gravity by imbibing or expelling water through lymph spaces or vacuolated cell regions. Thus correlation is made with density, which is associated with food habits, although a movement up and down does mean to pelagic forms what they do to land animals who live on the bottom of their sea of air, yet they are sometimes exquisitely oriented, although with no height or depth phobias like those common in man.[2]

Of course existing protozoans probably do not exactly represent the first forms of life either psychically or otherwise. They may not be proto-organisms in the sense of representing the original forms of life. Those studied above may have departed far from their starting point under altered conditions. Such reactions as are outlined in the last few paragraphs but samples the field in which all the data obtainable must be derived from which to infer primordial responses through the ages mainly before those represented by the oldest fossils. But it must have been somewhat thus that they reacted to the influences about them and to remoter teluric and cosmic forces. The rapports were so long, close and manifold, the plasticity was so great,

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[1] For complete reference see p. 212.

[2] See the author's Fears. *Am. Jour. Psychol.*, Jan., 1897, Vol. 8, pp. 147-249. Falling, p. 154.

and the retention of effects so persistent that we must seek the broad basis of the pyramid of which man is the apex here. Our minds as well as our psychological processes are derivative of these unconscious antecedents. The kinds of motor response may show great unity of formulæ and be conditioned by the shape of the body, but they are not those of a machine determined entirely by different tensions on different sides. Immediately after death the effects are different. Nor do these minute creatures react like small masses of protoplasmic substance, as Dantec thinks, but as individuals. Some respond very like muscles exercised from higher organisms, others move about as if in quest of definite objects like the white corpuscles in our blood, or like various digestive cells, and there are in vertebrates close analogues to ciliary movements. Cope,[1] strange to say, says that "The conscious cell is the primitive cell, and the unconscious cell is the independent or specialized cell," and adds, "Brain cells are the least modified of all those that constitute the soma of the metazoa, and thus they resemble most nearly the simple beings which constitute the lowest forms of the protozoa," and more lately amœboid movement, causing make and break of lines of conductivity, has been suggested between the processes of the cerebral neurons to explain associations and disassociations respectively. Watkins[2] even infers that evolution may be regarded as a compounding of minds and that man is a psychological as well as a biological colony, so that what we call psychic unity is not that of a simple thing but of a system. Verworn[3] thinks every cell, whether free and independent or aggregated in man, has something akin to mentality, so that mind is not superadded. Many hold that the physiological is a degenerate form of the mental. It is certain that the highest creatures are built up out of functions and structures of the most primitive kind and that rudiments and reverberations of the earliest forms of life are cardinal to our own, so that their study is the beginning of anthropology.

The world riddle of the lower limit of mind is far older than Des Cartes, who made the summary *coup* of declaring all animals to be automatic machines. Evolution, however, tends to trace mind further and further toward the origin of the universe and to assume continuity from the first, as it must do to work smoothly. The present recrudescence of Cartesianism had an able and representative expression in the attempt of Beer,

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[1] Cope, E. D.: The Evolution of Mind. Am. Naturalist, Oct. and Nov., 1890, Vol. 24, pp. 899-911 and 1100-1016.

[2] Watkins, G. P.: Psychical Life in Protozoa. *Am. Jour. of Psy.*, Jan., 1890, Vol. 11, pp. 166-180.

[3] Verworn, Max: Modern Physiology. Monist, Apr., 1894, Vol. 4, pp. 355-384.

Bethe and Uexküll, who proposed to objectify nomenclature.[1] For all reactions of unicelular animals and for plants they proposed the term antitypia, and for those of higher forms the term antikinesis or back movement. Receptive organs are called anelective if their states can be changed by stimuli of different quality, and elective if only a special kind of stimuli operates. Their terminology is both ingenious and elaborate. Psychology must be expressed in physiological terms. We cannot imagine what the ants feel or sense. Ziegler[2] would banish every philosophical term and rejects the idea of consciousness as "utterly worthless." Verworn in his protista studies uses the term stimulus movements (Reizbewegungen) as common to lower animals and plants, but adds to this spontaneous movements. The term *kleronomia* has been suggested for all inherited qualities which would include reflexes and most instincts as opposed to *enviontic* designating individuals acquisitions even the term psycic is called a vulgar designation for higher nervous functions. Massart[3] has given yet more detail objective nomenclature for plant and lower animal life, including the kinds of stimuli and reaction, strength, direction, intensity and results of each.

The criteria proposed for determining the lowest limit of mentality are many and diverse, and are perhaps about the best tests and keys to the philosophy of an observer. Of these, the power to choose or select one of two or more responses pleases those who emphasize free will, but is hard to apply for even inanimate objects between two opposite forces may differ in their response because of undetected and uncontrolled differences within or without, so that their action is not exactly predictable. If, and when all is known, man himself may be found to be only a complicated machine while the simplest thing that lives seems at times to show traces of freedom, and Metschinkoff thinks phagocites choose dead rather than living cells and tissues, and Wundt that they have some selective power with regard to their foods, qualities of light, etc. Those who hold vital adjustments to be mechanical may just as logically be told to draft their machine as may those who think a

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[1] Th. Beer, A. Bethe and J. von Uexküll: Vorschlage zu einer objectivireden Nomenclatur in der Physiologie des Nervensystems. Centralblatt f. Physiologie, June 10, 1899, S. Bd. 13, 137-141. Biol. Centralblatt, Aug. 1, 1899. Bd. 19, pp. 517-521.

[2] Heinrich Ernst Ziegler: Theoretisches zur Tierpsychologie und vergleichenden Neurophysiologie. Biol. Centralblatt, Jan. 1, 1900. Bd. 20, pp. 1-16.

[3] Jean Massart: Versuch einer Einteilung der nicht-nervösen Reflexe. Biologisches Centralbl., Jan. and Feb., 1902. Bd. 22, pp. 41-51 and pp. 65-75.

form of life is higher chemistry be told to synthetize it in the laboratory. The power to learn or profit by experience is another current criterion of mind, and closely connected with this are its definitions, as memory or associative memory and, with ability to rectify errors this concept usually draws the line between psychic and non-psychic far lower down even to the dawn of life for an essential trait of protoplasm is its educability by its environment. Semon's[1] mneme includes every effect of a stimulus that persists after it is removed and assumes that plasma is water to receive and steel to retain. Radical as it is, this conception is better, but highly speculative and lends itself to the very abandon of mystic dreamery, yet the scientific imagination has perhaps never found a field for such wholesome and stimulating suggestion as in the modern plasma cult, fulfilling here the highest function of theory. On the whole, it is also the most objective of tests for psychic rudiments and experimentation, and permits less ambiguity in interpreting results. As progressively exact adaptation, life itself is at least quasi-psychic, developing as if informed by an intelligence far superior to man's, with more wisdom implicit in an amœba (to know which completely would be to know all) than in the most comprehensive cosmic philosophy. A third group of tests is affectability, feeling-tone, elementary pleasure and pain. An animalcule that has attained food, its thermal and luminous optimum, and rests, must be assumed to have attained a modicum of satisfaction. But here interpretations differ widely. Is it due to the selection of a future end and of the means thereto, or is it tropism? When Norman's[2] earth worm was cut in two in the middle the anterior part crawled on with little disturbance, while the posterior half writhed as if in agony, and the same result was seen if the front half was bisected again. When the ant and even Bethe's[3] bee was severed at the abdomen, the front end where the cephalic ganglia were situated, kept on sucking honey which flowed out at the middle. It is hazardous to infer sensation from movement, and yet these are our only bases of inference and the motive of selection and the struggle for existence is assumed to be the

[1] Richard Semon: Die Mneme als erhaltendes Prinzip im Wechsel des organischen Geschehens. Engelmann, Leipzig, 1904.

[2] Norman W. W.: Dürfen wir aus den Reactionen niederer Thiere aus den Vorhandensein von Schmerzemfindungen schliessen. Archiv für die gesammte Physiologie, Apr., 1897. Bd. 67, S. 137-140.

Also, Do the Reactions of the Lower Animals against Injury Indicate Pain Sensations? Am. Jour. of Physiol., Jan., 1900, Vol. 3, pp. 271-284.

[3] Albrecht Bethe: Vergleichende Untersuchungen über die Functinen der Arthropoden. Pflüger's Archiv für Physiologie, Oct., 1897. Bd. 78, S. 509-545.

attainment of agreeable and the escape from disagreeable states. Hence with this genus of tests we can do little or nothing. To all this Wasman[1] vigorously suggests that instinct cannot be resolved into botanical tropisms. Moths often fly at right angles to the flame instead of being drawn into it as by a magnet. Caterpillars creep up twigs to their tips as if positively heliotropic, when they are hungry, but lose this power when they are sated. How, he asks, could they turn about when they have eaten the twig clean and so not die of starvation? The truth seems to him to lie somewhere between a segmental and a centrally located seat of instinct and he deems the array of objectivizing terms useless pedantries, and defends the use of analogies, with human experiences. Consciousness proper he would limit to the last stages of evolution and probably to man, and he thinks evidences of it diminish just in proportion as we recede downward from minds like our own. We must not becloud the theory of reflex action. Yerkes goes so far as to suggest that the ant with its exquisite senses, docility and social life "possesses a form of consciousness which is comparable in complexity of aspect with the human." The sanest conclusion perhaps, is that "the theory of tropism does not go far in helping us to understand the behavior of lower organisms; on the contrary, their reactions when accurately studied are, as a rule, inconsistent with its assumptions." Jennings[2] thinks that the method of trial and error is the most essential feature in their conduct. Tropism is "a fixed way of action pressed upon the organism by the direct action of external agents," each class of them having its corresponding tropisms. Stereotyped reactions do occur, but there must be some way of distinguishing error from success, for after several trials error tends to be avoided. He holds that these reactions are of a much more flexible and less machine-like character than the theory admits. The trial and error scheme "leads upward, offering at every point opportunity for development and showing even in the unicellular organisms, what must be considered the beginnings of intelligence and of many other qualities found in higher animals."

For one, I prefer to defy the current horror of anthropomorphism and to show a decent respect to continuity. Wherever the term consciousness is introduced there is confusion and no one ever yet accepted another's definition of this pro-

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[1] E. Wasman: Einige Bermerkungen zur vergleichenden Psychologie und Sinnesphysiologie. Biol. Centralblatt, Mar. 15, 1900. Bd. 20, S. 342-350.

[2] Herbert S. Jennings: Contributions to the Study of the Behavior of Lower Organisms. Carnegie Institution of Washington, Washington, 1904.

tean term. Only to speculative and monodeistic minds can the question between some psychic rudiment and tropism be so put that we must cleave to the one and despise the other answer, for both are at the same time true, and both are involved in the same reactions. Each sheds light on, and perhaps is necessary to, the other as are mechanism and life, and only dogmatism, unscientific partisanship, a passion for premature conclusions and hazy faith in what some far future will show, can take sides or strive to precipitate an answer to this unusual and inscrutable cosmic riddle. To say that a miser is chrematropic; a religionist, theotropic; one who loves home, œchotropic; a sailor, pelagotropic; a drunkard, methutropic; that when we are hungry, we are sitatropic, that boys who love girls are parthenotropic- , taxic-, tonic-, kinetic-, phobic, positively, negatively, etc., would be true, but not the whole truth. Some supernal being from a distant planet large enough to need a microscope to see man, might describe us in such terms in the early stages of his knowledge of us. What is wanted is not so simple a formula, but details, variations, the origin and history of such appetency; and so summary a terminology is sure to tempt many to rest in a sense of finality, and not to recognize it as merely a set of names for our ignorance and spurs to further investigation.

Finally, sagacious as are all these experiments, and valuable as are the results, we must not forget that they are narrower in scope and less characteristic than are the data that come from patient investigation of life histories in natural habitats from birth to death. While some of the lowest of these creatures tend to respond exactly in the same way during the very act of dividing, and the young act just like the old, the conditions of experimentation are often more or less strange to them, and are often far more specific than anything in their previous experience. Just as no laboratory tests have yet been devised that satisfactorily calibrate the general ability of children and even school work and examinations fail to do so, so these lowly creatures have a free, spontaneous life outside, often with daily, seasonal and age variations. Wherever a larval state can be detected and studied, however brief it may be, its reactions are as different from those of adults as are its forms. Power to adjust suddenly to change is overestimated by the old pregenetic conception of mentality. The naturalist's method seems too simple to the modern experimenter with his new arsenal of apparatus and exact methods. Of course, some of the elementary microscopic forms could not be studied by direct observation in their home conditions and must be domesticated under a cover-glass so that the problem how the creature lives out its fully rounded life in the normal condition to which it is most

addicted is more answerable for the larger and higher forms to which we now turn.

Our next general group must, therefore, comprise roughly, the forms now thought nearest to those represented by the earliest fossils that are at once abundant, fully featured and pre- or sub-vertebrate, and which, like, *e.g.*, the trilobites of the Ordovician age (when they were represented by seventy-seven genera, declining to thirty-one in the Silurian and tapering to —in the Tertiary,—a creature which seems to have both run and swam and had tactile antennæ) are known to have passed through a series of marked developmental stages from the time when the young were old enough to fossilize and maturity. From this we may infer that the species had already undergone long stages of evolution which individual members of it were recapitulatory when they first appeared in the rocks. Psychic development in this age probably "approached somewhat nearly to that now possessed by correspondingly low types." "Higher biological types within the same order have certainly developed since in many cases, and probably higher mental functions, but some of Ordovician forms have suffered biological and probably also mental degeneration."[1]

Of instincts on this higher plane that show distinct genetic features, perhaps no modern forms that have been so well studied are more likely to be typical and suggestive of the cephalopods and gastropods that were typical of early Paleozoic times, than the modern fresh water snail, Physa studied by Dawson and allied forms by Cole (1) and Yung (10), very like the ancient gasteropods observed by Montague, Tait, Tye, Tryon, and Adams. Not only are there great individual differences, but young snails seem less sensitive than older ones, and act somewhat as the older ones do when tame. Those half-grown recover quicker than adults when equally disturbed. Very young snails rarely tap with their syphon when placed in a beaker directly from the pond, as older ones do, and their spontaneous and stimulated movements are simpler. Like all the helix forms of molluscan shells their type of growth suggests evolution and progressively "larger mansions for the soul" and body. Studied first over several hundred acres in Michigan, where they abound, they were found to be minutely adapted to their optimum conditions, having chosen marginal and littoral zones, temperature, shade, sedge, decaying debris, and to have provided for possible desiccation, for Physa does not burrow like bivals, and forms no epiphragm to withstand drought. As it creeps along the bottom it spins a ribbon of slime, and when

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[1] T. C. Chamberlain's and R. D. Salisbury: Geology. Vol. II, p. 364. H. Holt and Co., New York, 1905-1906.

it needs to rise this is curled into a tube and anchored so that it can stop anywhere in its upward course. On reaching the surface film it turns its body about and its disk takes in oxygen. Here it feeds, and in going down after attaching to the surface it spins another line, which is at first transparent but which may be used several times even by other snails. Like other pulmonates it can rise or sink according as its lung is full or empty. Carmine grains show that these lines do not stretch, although they may be a foot or two long. . If it turns before reaching the surface it gathers in the line. It rises steadily like a toy balloon till within perhaps a centimeter of the surface and then accelerates, having a strange sense for a surface or for a solid which lies in its course before reaching it. It rarely spins a downward thread if its lung is empty. A hair may be accepted and used for a line of their own make. The tenacity of the mucus and of the spinning of its thread depends upon the intake of food, and it is less strong than the threads of air spinners, like spiders, which must sustain their weight. It seems hard for a well snail not to spin, but they cease to do so during hibernation or during cold or darkness. In flowing water they rarely spin but hug the bottom tighter to avoid being swept away. Fine gravel, stems and a rough but not precipitate bottom, which favors anchorage, increases the tendency to spin. Although they rise chiefly for air they do not always do so at the time of greatest respiratory need so that there are other, perhaps mechanical, impulses to that act. Physa is very sensitive to jars upon the surface even though it may lie some distance below it. This sense causes them to react on a tadpole or beetle that comes near them. When placed in deep water they always turn toward the shore and they rise and descend almost vertically, and seem to detect very slight angular difference from the line of gravity. When moving along the bottom, especially if it is an unaccustomed one, they project their syphons into long tentacles and tap along like a blind man with a cane. Wherever they are they at once seem at home as soon as they touch the surface film. The soil of a certain consistency in contact with the head seems to be stimulus for burrowing. It is important to observe the daily life in a native habitat before transference to aquaria, although snails readily adapt themselves to any conditions and can be tamed, and even accustomed to being handled. Other studies show that snails have considerable sense of direction. Land snails can retrace their course probably by a trail of slime for rods; seem attached to their mates and to localities. Closely allied forms react to odors (Sprengel), heat, light and even sound, taste (Nagel)[1] and others to geotactic stimuli in a way which

[1] Wilibald A. Nagel: Der Lichtsinn augenloser Thiere. G. Fischer, Jena, 1896.

is measurable (Davenport),[1] while intense light provokes, in Physa, great activity, with growing insensitiveness to mechanical influence and subsequent exhaustion (Pearl).[2]

As the snail and bivalve type of life of the Ordovician may be slightly inferred from their highest modern relatives or descendants, so the life of the great crustacea of the mid Silurian age which reached their culmination in the Eurypterus of the Devonian and carboniferous period may be, at least, to some extent approached from the study of modern crabs. The great restriction of shallow sea area in the Silurian era, which shows more species than any other during the tertiary and the adverse conditions attending the closing paleozoic period did not restrict their orthogenic development so that their pauperitic forms are few and this attests the vigor and the value of their structural and ecological paradigm of life. Rock crabs have keen and far sight, are timid and fly to their hole at the slightest alarm. They cannot live long under water and if they are frightened off a beach, dig themselves tight into the sand at the approach of every great wave. Land crabs travel by night in swarms, in May and June, and always in straight lines, even over houses to the shore, where they bathe a few times, lay their eggs in the water, and return to the mountains. One small species of crustacean builds conical nests of sea-weed where they rear their brood. During the moulting season, the common hard-shelled crabs are said to post sentinels to protect their comrades during their unprotected state. The lobster buries the uneaten part of its food in a heap of gravel and mounts guard. Certain crabs open cocoanuts by an ideal, invariable and the only way possible for them. Other aid anemones, which are their commensals, in attaching themselves to their shells. Even the young hermit crab, when he is first given shells or molluscs rushes to them, hesitates, mounts the mouth, and rides about until the tenant is dead, and then it tears it out and takes its place. Their love of change and activity impels them often to accept new and worse shells. In changing, the crab explores, passing from one to the other home, as if comparing by trial and use, and at last darts quickly into the new one. They pass through six metamorphoses before reaching adolescent[3] form, suggesting recapitulation of, so far, unexplored phyletic stages, and their bodies by this time soon become very asymmetrical, perhaps because they strongly prefer dextral shells. Yet young ones can adjust themselves

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[1] C. B. Davenport: Experimental Morphology. Vol. I. The Macmilmillan Co., New York, 1897.

[2] R. Pearl: The Movements and Reactions of Fresh Water Planarians. Quart. Jour. Med. Sci., Vol. 46, pp. 509-714.

[3] See Thompson: Proc. Boston Soc. Nat. Hist., Sept., 1904.

to sinestral shells with less inconvenience than the old ones. Spaulding's[1] experiments (1904) on hermit crabs with the simple maze showed that they could profit by experience in association by vision and taste, and he believed that they could "reproduce, or if one will, vaguely remember." Yerkes[2] (1902) has shown that the crawfish can slowly acquire a simple labyrinth habit, and learn to turn always the right way to food when the chemical senses are excluded, some fifty to one hundred trials having established an almost invariably right choice of one out of two passages. He later showed that the green crab could be taught to go in a nearly straight line to its food instead of following a devious path as on its early trials. Dearborn (1900) found a little less individuality in the crawfish than he expected, but found them very susceptible to horrification and that touch was more important in their lives than sight.[3] Rotation produced no trace of vertigo. He measured their traction power and pinching strength. If they could not, when placed upon their backs turn over within five minutes, they gave it up. Most could be "hypnotized" by holding them still for about a minute when they became rigid, for ten or twenty minutes and aroused themselves suddenly. There was far greater variability in the conduct of each individual at different times than difference between one individual and another. Testing reaction time required painful stimuli, causing great psychic irritation. Inconsistency and absence of correlation between the results of the various tests was one of the last writer's conclusions.

Perhaps the first air-breathers were the upper silurian insects, the cockroaches and scorpions, the fossils of which show true spiracles, but it is certain that insect life had already begun upon land in this primeval age. All the Devonian insects which were rather abundant, as land vegetation was increasing, seemed to belong to the old net-winged order, some of them had chirping organs which of course implies hearing. It is amid the rank herbage of the carboniferous age, however, that insects appeared in great numbers and in many varieties, especially dragon flies, grasshoppers, cockroaches, spiders, scorpions, centipedes, etc., although flies, butterflies, bees, ants and social insects generally were still wanting. Honey-lovers had to wait the appearance of true flowering plants. Some insects of this age are found in vast numbers and among them occurs the largest insect known, the phasma, a foot long and with a 28 inch spread of wings. All the hexapod palæozoic insects are

[1] E. G. Spaulding: Jour. of Comp. Neurol. and Psychol., March, 1904, Vol. 14, p. 49.

[2] Robert Yerkes: Habit Formation in the Green Crab. Carcinus granulatus. Biol. Bulletin, Oct., 1902, Vol. 3, pp. 241-244.

[3] For complete reference see p. 212.

highly generalized, some inclining to each of the three now widely separated orders, neuroptera, orthoptera and hemiptera. When we come to the Jura some 150 species are known in the trias alone, of which three-fourths are beetles; here, too, the higher groups begin. Even miocene vegetation was much more abundant than now, and more tropical, hence insect life was more plentiful and all orders including the highest are found. Some 2,000 fossil specimens having been discovered, some bits of sedimentary rock being black with their remains. In all Europe there are now 50 species of ants, but Heer found more than 100 species in a single miocene bed all winged. From this he inferred that loss of wings and the development of neuters came later in connection with the further evolution of social habits since the early tertiary. The miocene indusial limestone in France is a cement of cast off cases of the larva of the caddis fly. In several tertiary amber beds made of conifer resin over 800 species of insects have been perfectly preserved, and Scudder found 1,000 species including 7 out of the 16 known fossil species of butterfly in the Green River Shales.

Insects are now represented by many hundred thousand species and varieties, the oldest forms of which can be traced to the earliest geological age, and in them the marvels of instinct culminate. Insects live in the earth, air and water, construct intricate homes of many typical and purposeful forms, provide with amazing sagacity for the food and shelter of their young before the eggs are laid, by choosing a place within or upon animal bodies, plants, soil where they are sufficiently or best nourished, lay in the kind and amount of provision needed, devise many ways of preparing, preserving and accumulating food, and guarding it against robbers. They care for their eggs in elaborate ways, domesticating and rearing slaves and pets, seem to plant and harvest and cultivate fungus-gardens, gathering honey and pollen, secrete wax, silk, chitine, cellulose, poisons, develop many kinds of warning color, organize communities so elaborate that they are comparable with human social and political organizations, spin webs with vast mechanical difficulty and make balloons and float off on them, migrate great distances and in the utmost order, organize forays, fight pitched battles, carry on campaigns, have senses and modes of communication we cannot understand, show memory, fear and anger, migrate and hibernate, and seem to be hypnotizable, have intricate modes of reproduction, show memory both active and passive, have definite habits of individual cleanliness and of domestic and public hygiene, construct and set traps for their prey, besides their hard work have play spells, develop funeral habits, have a strange but usually unerring sense of direction, educate their young to pass through

distinct developmental stages after as well as before beginning their active life, construct almost mathematical cells, are masons, tapesters, carders, make diving bells, trap doors, have complicated customs of marriage flight and swarming, and do so much of the cross-fertilization of plants that most of our flowering species could not exist without them. From even such mere chapter heads of entomological psychology (to the detail study of which scores of the ablest minds of the present and recent past have given their lives and developed a vast literature in a field, which for its purely scientific as distinct from its highly economic value, university chairs should be established), the question arises and just in proportion as we read and observe, grows insistent whether if intelligence is adjustment and the accumulation of the results of experience, any other form of life, not excluding man himself, has attained any such perfection. Certainly none of the higher vertebrates can compare with insects in this respect. Their typical and communal activities and their individual ingenuity and inventiveness in meeting unusual emergencies are alike extraordinary, and the naturalist in this field meets with what Huber calls "brilliant flashes of reason." Experimental tests with insects show both surprising limitation to modes of response and also amazing cleverness in the original solutions of the problems presented. How could the ant, *e. g.*, have better met its conditions of life, structural and environmental, if it had from the first been endowed with human reason? Must we not conclude that psychic organization of the insect world is due to the fact of its age, for it is perhaps hundreds of times older than man? Its teeming populousness, too, has all this time made its social stimuli relatively greater than the environmental stimuli as compared with species with less individuals, so that mutual help has thus been more developed.

The above three types, not in man's line of descent, but which are far lower than even his animal pedigree and can be traced with much certainty, show not only great development of digestive, eliminative, and motor apparatus, respiratory, circulatory, reproductive, nervous and sensory mechanism and function, but cumulative and recapitulatory heredity, as well as stages of somatic and psychic evolution. The spiral and enlarging shell begins with the foramenifera, the nautilus, the only surviving representative of the once large and numerous tetrabranchiata, retiring from each chamber as it grows larger, and maintaining connection with all only by its siphuncule. The method of growth of the crustacea is by successive moults and that of insects by metamorphosis, the larvæ of the latter often showing more sagacity than the full imago. These three methods of development are all recapitulatory of the history of

the race, and have long been standing tropes of evolution to higher stages. Another conclusion forced upon us is that every tool, apparatus, muscle, structural part is certain to be utilized to the very uttermost. A carapace is strong and hard just where and to the degree that there is actual strain or attack. A claw or tentacle, eye, limb is used in every possible helpful way, and just as there cannot be any perfect living brain without a mind, and perhaps *vice versa*, so structure and use are one and inseparable. Every curve, hue, contour and size may be a matter of life and death, every mottle in the wing has a sufficient cause and each sportive variation not at once helpful tends to vanish. Prodigal and wasteful as she is of individuals, nature went through long and hard labor to produce types and so is very economical and careful of them. Even earlier forms that have gone the way of the lost cystoids of the Cambrian, the astrocods of the Silurian, and the ammonites and blastoids of the Devonian, and many others that seem to have vanished have, in fact, doubtless persisted in direct continuity in forms that varied beyond our power to trace them during the dark ages of transition, so that instead of dying, between the two successive but unconforming geologic periods, the old forms were transmuted beyond our power to recognize them. Precisely the same is true of other phyla. Many types of soul life have vanished or been transformed. Very likely vertebrate life would have seemed at this early stage aberrant or decadent, for its powers of adaptation to the manifold environments were probably far less than those of insects, which to the philosophical onlooker would have seemed the crown and entelechy of animal existence. A question we cannot answer is whether forms that were long ago more diverse, larger or abundant, also had in their early day a proportionately and higher development of instincts, so that their modern survivors have followed the law of once high and then decadent human stirps in repeating, in a conventional rudimentary way, conduct once far more evolved. This, however, would seem to harmonize with the mechanical nature of many responses, while the power to solve new and individual problems suggests that some instincts may be still in a process of formation. To my mind the most probable statement that can be made is that insects now do much that was learned in the early stages of their phyletic development, so that in observing them we are often face to face with processes far older than man or the present geological configuration of the globe. It is this momentum that makes animal instinct generally, and especially in its lower forms, so automatic. It need never have been discursive, but it is now chiefly innate, and in it is the condensed and impacted experience accumulated from an almost infinite number of generations,

the momentum of which impels nearly all the activity of these lives. It is thus impossible to account for them if the condensed results of experience are not, at least in some degree, inherited. Again, most insects with higher instincts are social, and a few now solitary were once so. A community is an instrument by which the aggregate develops the ability to profit by the smallest groups or even individuals within it. Not only division of labor, but the fact that each cell as it were of the body politic moves about, all of them combined over a wide area encountering divers chances, and then when they come together have some power of imparting and following their experiences, makes for manifold orientation or plasticity in the state. Higher animals are intelligent and domesticable, somewhat in proportion to their gregariousness in feral states, and ants and bees and other insects huddle and mutually impart their psychic states by contact as if they were parts of one body so intimate is their intercourse, yet each goes out by itself and accumulates impressions as it does food and honey for the common good. Thus they are "separate as fingers, but one as the hand." Observation and experiments show great difference among individuals and there are geniuses and fools in every large colony and swarm. Yet in the insect city the individual is more subordinate to the community than in any known higher form, hence, there is greater harmony with never a real ruler. Insects were, perhaps, the first forms of animal life to permanently emerge from the primeval sea, and if so they thus have the start of all others in adjusting to new and more complex situations. It is practically certain that they were the first to fly, adding thus a new and even physically larger field of experience.

The natural order of studies of life is first, classification and nomenclature, involving inner anatomical structure, then the study of life histories of individuals, a far more important and intricate work for which taxonomy is merely preparatory and of which we as yet know very little and that only of very few species. Even our acquaintance with terrestrial forms is limited, while of fresh-water and especially pelagic types we have but the slightest knowledge even of the species, the morphology of which is found in our text-books. Very likely many still unstudied are yet more remarkable than the highest yet known.[1]

[1] Daniels, Scudder, Lacoe for years collected fossil insects in this country and lately all those in our national museum were handed over to Professor Handlirsch, of Vienna, who found among them 137 new species, and has classified and located them so far as possible in the successive geological strata, especially those that belong to the coal measure and the Permian Age. Little is known of the horizontal distribution of these insects, but the similarity of the American to the

Thus of the life histories and the evolution of instincts, which ought to be the goal and the key of all, our ignorance is painful. Among the boldest and most important beginnings in this field are the attempts of a few pioneers like Buttel-Reepen, to construct the genesis of the social organization of bees and ants.[1] He thinks division of labor the *primum movens.* First the female hives alone, the male having vanished after the nuptial flight. The nest is of one cell and apart. Here the mother lives and dies alone before the young appear, each from its own hole in the earth. Next the mother finds it easier to give to several cells a common exit, and by thus economizing labor she can lay more eggs. This development was accelerated and the mother continued to lay longer till the first eggs hatch before she is done laying, and mother and offspring meet and the family begins. Some of the young do not fly out at once but help the mother build and provision the last cells. In parthogenetic species the young may even help the mother lay eggs. These individuals may never become fertilized so that they become sterile workers who stay at home while the males rove. Later, as now with wasps and bumblebees, the young female is fertilized in the fall and in the spring builds, and rears a brood, defending them and bringing food. Slowly the mother becomes only an egg layer and very fecund, while the workers lay no eggs, so that as the young and the queen are tended by the workers, each depends upon the other. This view shows how workers are derived from queens, which as opposed to current views that males vary more than any other members of a community. In some ants, besides the normal winged queen, there are often fruitful queens without wings. Workers are thus distinguished of different sizes and with different functions, and a soldier caste arose. Buttel-Reepen even attempts a genesis of the fungus garden of some ants. He found one queen which in several important respects repeated this genetic history, even living peacefully with another queen for a time, till the future colony was assured, then killing it. Quality or quantity of food, and perhaps both, aid in the fur-

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European species is very striking. As a result of comparing the number of forms in the single orders of the Paleozoic Age the paleodichyoptera seem to be the stem group on morphological grounds. It also appeared first and then steadily gave place to the seven more specialized orders, which latter are transitional to modern insects. These seven orders appear in their maximal numbers in the middle beds of the Paleozoic before giving place to the newer forms. Revision of American Paleozoic Insects, by T. R. Proceedings of the United States National Museum, Vol. 29, 1906, pp. 661-820.

[1] Die Stammesgeschichtliche Entstehung des Bienen Staats, Thieme, Leipzig, 1903. Also Wie entsteht die Amiesen-Kolonien. Arch. f. Gesellshafts Biologie, 1905, p. 20.

ther development, polymorphization and the division of labor. The evolution of the ant state, as he describes it, while following a somewhat different course, shows a more elastic organization than that of bees, including as it does aphids, etc., a greater independence of its members, more all-sided adaptation to food and forms of dwelling, and hence it has more power of persistence. Escherich who has studied ants for nearly half a century, thinks many phyletic features can be made out when we compare the over five thousand species and varieties of formicidæ, and holds that the workers with their larger brains have led the way. He believes they were winged at first and that those now so have reverted, Poulton suggests developmental stages for insect mimicry, and derives the wet phase of some dimorphic butterflies from an older dry phase, the two being often so different as to be thought distinct species. Wheeler[1] suggests a phylogeny of parasitisms and the results of mixing members of different nests and races, of slavery, etc. The data in all these cases are comparative and cannot be very firmly based on, or even connected with, paleontology.

For our part we believe the long period of inveterate and incessant disparagement of instinct and even of highly adaptive reflexes as unconscious and automatic and as lacking in the indefinite and very much over prized element of consciousness or discursive reason is passing, and that the future will see an opposite tendency, viz., that modes of life that fit the nature and needs of the species with exactness will be deemed high just in proportion as they have become blind and mechanical and therefore, securely established, and that man would tend to be morally and intellectually better if he did and thought rightly in all important matters as a music-box, when wound up, plays the right tune, with proper expression to the end, however long and complex it is. The superiority of instinct over reason is that it regulates conduct in the interest of the species at every point while consciousness is selfish and is exactly measured by the degree to which the individual has broken away from the dominance of the race and set up for himself against it. This is a disease of our infant race, but it is a grave one that threatens the very attainment of man's maturity. If our venerable animal forbears passed through such a stage of consciousness (as perhaps they did in various degrees when they were young as we are now) without becoming permanently aberrant, and reached their present perfect adjustment or else became extinct in exact proportion as they conformed to their law of life or swerved from it, then the chance of man's renormalization from the fall is perhaps about as grave as all religions make it.

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[1] W. M. Wheeler: Nests of Ants. Am. Nat., July, 1903, Vol. 34, pp. 431-513.

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